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No. 123

Civil Air Defense Project Design Standards

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CHINA REPORT

Science and Technology

No. 123

Civil Air Defense Project Design Standards

Beijing RENMIN FANGKONG GONGCHENG SHEJI GUIFAN in Chinese 1980 pp i, 1-86

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PREFACE

The guiding principle of making overall planning, stressing priorities, coordinating peacetime with wartime conditions, and emphasizing quality must be followed in the construction of civil air defense projects. These projects must be solid, suitable, economical and rational. They should serve socialist construction and the people's livelihood during peacetime, as well as insuring that they can cope with the enemy's air raids and help to wage steadfast struggles in the cities.

These standards are applied to the three types of civil air defense projects--tunnels, tunnel fortifications, and dugouts--that can resist ground ultra pressure of 1 kg/cm^2 and 3 kg/cm^2 caused by shock waves from a nuclear explosion. The emphasis is on tunnels sheltering personnel, which are used by engineers and technicians engaged in building civil air defense projects. The contents of standards [or provisions] that are similar to those pertaining to tunnels, caves, and industrial and civil buildings are not listed here and, in this regard, the relevant state standards (or provisions) must be followed.

CHAPTER I--CONSTRUCTION

Section 1. Basic Requirements

1-1-1. Civil defense construction projects must be integrated with urban and capital construction projects. They must also have unified arrangements, overall planning and rational distribution so as to avoid interference with ground surface buildings, underground pipelines, and other underground structures.

1-1-2. Every effort should be made to build tunnels in the mountains and on high ground in the city to utilize fully the capacity of natural protective cover layers.

In the plains, deep tunnels must be dug. The depth should be based on utilization of the tunnels and the force of resistance. These projects are determined by comprehensively analyzing the aspects of economy, construction conditions, and easy access to exits and entrances.

In case of difficulties encountered in the deep excavation of tunnels where the underground water table is high and soil conditions poor, it is possible to build dugouts. However, the thickness of earth-covered roof must meet the requirements of preventing early stage radiation.

Note: "Tunnel fortifications" mean employing the "undercut" method of building tunnels in the mountains. "Tunnel" denotes the employment of "undercut" method of building tunnels on flat land. "Dugout" means the employment of the "open digging" method of building single construction projects.

1-1-3. A civil defense project must be a project of networks that is flexible and linked together to facilitate dispersion. It can be divided into a number of protective units in accordance with the administrative unit, tunnel utilization, and force of resistance. Each protective unit itself becomes a system.

1-1-4. A civil defense project must integrate peacetime with wartime conditions. It must benefit peacetime use as well as meet wartime requirements. Appropriate measures must be taken with respect to flat surface arrangements, ventilation and filtration, decontamination, power supply for illumination, water supply and drainage, airtight protection, communcations, moisture and humidity prevention, and indoor installations and repair in order to insure the protection of personnel and the necessary conditions for livelihood.

1-1-5. In a civil defense tunnel project, the axis of tunnel alignment, position of exit and entrance, and type of flat surface arrangements must be rationally selected in accordance with the protection and application requirements, the topography, geology, hydrological geology, underground pipe network, and local normal wind direction so that the air in the tunnel will flow freely and natural ventilation will be fully in effect.

1-1-6. The exposed position of civil defense tunnels, such as exit and entrance, air inlets and outlets and smoke exhaust openings must be camouflaged, and the methods of camouflage must be in accordance with the prevailing local conditions. The materials being used must be locally available to achieve the effects of environment harmony. Considerations must also be given to the feasibility of clearing debris from the area following a destructive blast.

1-1-7. Civil defense projects must be far away from the major targets that are susceptible to attack by the enemy, workshops and warehouses susceptible to fire and explosion, as well as tanks storing large quantities of toxic liquids and toxic heavy gases.

1-1-8. The interior fittings of civil defense tunnels should be simple, austere and suitable. Fittings must be obtainable locally. Use moisture-proof, rot-proof, and incombustible materials. All pre-storage items must be given anti-corrosion treatment.

Section 2. Flat Surface, Sectional Designs of Tunnels

(I) Flat Surface Arrangement

1-2-1. The flat surface arrangement of civil defense tunnels must be consistent with the following requirements:

a. The location of tunnel fortifications and tunnel projects must be so arranged that the protective layers are fairly thick and geological conditions favorable.

b. Zoning must be clear-cut and definite; contact convenient; and mutual interference minimum.

c. There must be a simple configuration, favorable to natural ventilation, easy to construct, install, and repair.

1-2-2. Axis arrangement must conform to the following requirements.

a. The alignment of the tunnel axis must avoid effects of pressure from building wall foundations.

b. The alignment of the tunnel axis should go through the section where the rocks are complete and stable and follow the width and thickness of the mountain shape. Avoid faults, melted caves, and geologically crushed bands. Also, make it perpendicular to the alignment of the rock layers.

c. The deflection angle of axis must not be less than 90°. When the axis is intersected, its minimum included angle should not be less than 60°. When transportation is required, the angle of deflection must be shaped like an arch. Its curve radius must be determined on the basis of utilization. Generally it should not be less than 10 meters.

1-2-3. Room arrangements must conform to the following requirements:

a. Noisy rooms must not be near quiet rooms.

b. Rooms that diffuse large amounts of moisture must be kept a distance from rooms requiring high humidity.

c. Rooms that are susceptible to fire and explosion must have independent arrangement. Protective airtight doors must be installed in joint passageways to separate the rooms from the main body.

d. Rooms that release poisonous gases must be located near the exhaust outlets. Polluted water pools must be located in the direction of the downhill drainage slope.

1-2-4. Room arrangements should take the following forms:

a. For personnel shelters in tunnels, tunnel fortifications, and operations rooms, parallel passageway type, winding corridor type, double-lane or multiple-lane type (Figure 1-1) must be used.

b. Corridor-type, middle passageway-type, single-span, double span, and multiple span continuous type (Figure 1-2) should be used for personnel shelter in dugouts.

c. The perpendicular passageway type should be used for rooms producing noise.

1-2-5. Adopt the following specifications for areas of utilization.

a. Personnel shelter tunnel 1 m^2 person;

b. Command, communications tunnel 2-3 m^2/person

c. Hospital, first-aid station (including wounded personnel and operation personnel) 4-5 m^2/person

Note: (1) The above-cited areas of utilization do not include the areas of the airtight doors of the innermost passageway in the tunnel, of air, water, and electric power equipment rooms and of living subsidiary facilities rooms in the tunnels.

(2) The number of hospital health personnel is based on 50-80 percent of sickbeds.

1-2-6. Regarding natural ventilation in the tunnels, use the exist and entrances as air intakes and exhaust outlets. On the basis of the organization of airflow, use the construction vertical shafts as vents in the tunnels. Add ventilation vertical shafts in the dugouts. Do not use vent holes with small diameter and in large number.

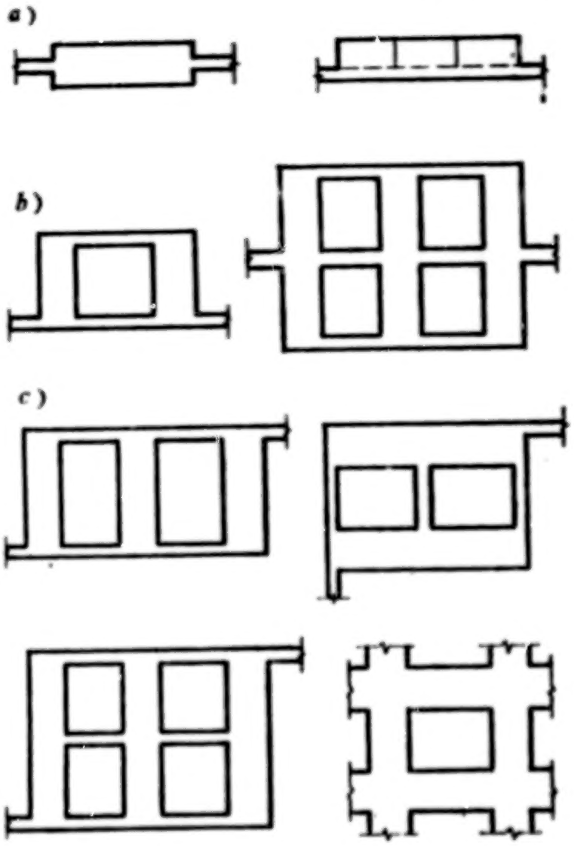


Figure 1-1. Flat surface layout of rooms in tunnels and tunnel fortifications
a) parallel passageway type; b) winding corridor-type; c) double-lane and multiple-lane type

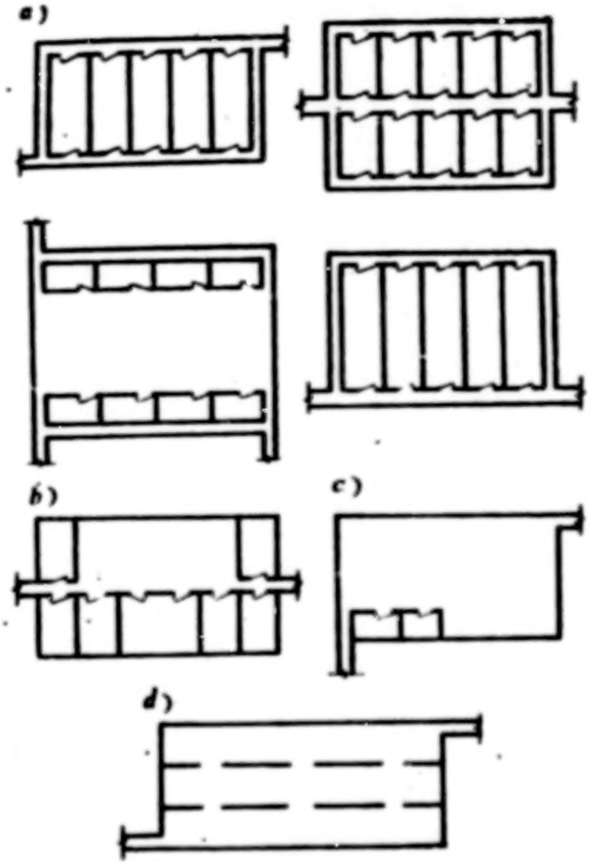


Figure 1-2. Flat surface room layout of dugouts
a) Winding corridor-type; b) middle passageway type; c) single span-type; and d) multiple span passageway-type

1-2-7. Installation of natural ventilation outlets must conform to the following requirements:

a. The number and location of ventilation outlets must be determined by the flat-surface layout of the tunnel, construction area, and organization of airflow. Each tunnel must have no less than one air inlet and one air exhaust outlet. When the outlet and inlet are used as natural ventilation openings, the angle of deflection between two passageway axes should not be less than 90°.

b. There must be a height differential between the natural ventilation openings. The high openings should be located in the positive pressure zone of the main winter wind direction.

c. The ventilation vertical shaft must be located at the end of the passageway or outside the sidewall and is connected with the short passageway. It must not be installed directly on the roof.

d. The vertical shaft can also serve as standby exit and entrance for the personnel. A climbing ladder is installed inside the shaft. The shaft openings must have facilities to prevent personnel from falling and rain water from gushing into the tunnel.

II. "Area" Design

1-2-8. In tunnel "area" design, such factors as type of tunnel, applications, requirements of inside equipment, geological conditions, building materials, and construction conditions must be taken into consideration so as to make the structural form simple, weight-bearing capability good, sectional dimensions appropriate, and application requirements satisfactory. Specifications should be uniform and categories reduced.

1-2-9. Dimensions of passageways are generally specified as follows:

a. Joint passageways: net width 1.5-2.0 meters, net height 2.25-2.5 meters; height of spring line not less than 1.5 meters.

b. Trunk passageway

Pedestrian main trunk passageway: net width, 1.5-2.0 meters; net height, 2.25-2.5 meters; height of spring line not less than 1.5 meters.

Note: (1) "Main trunk" denotes passageway linking the city proper with the suburbs. "Branch trunk passageway" denotes tunnels linking various sections into a network and the pedestrian passageways linking the main trunk passageway.

(2) Net height denotes the height from the tunnel's flat surface to the vault's under layer.

1-2-10. Covered Type

a. Straight wall arched-roof wall-type coverings (Figure 1-3) are generally used in tunnel projects. When the moisture-proof requirements are fairly high, it is necessary to have linings inside the wall coverings (Figure 1-4).

b. Straight wall arched-roof wall-type covering or gunite support is generally employed in tunnel projects (Figure 1-5).

As to tunnels with high moisture proof requirements, when the rock quality is good, it is necessary to employ separated wall-type coverings (Figure 1-6). When the rock quality is poor, linings may be added to gunite support or wall covering.

c. Straight wall, arched-roof, multiple-span, continuous structures and frames and shell structures may be used in dugouts.

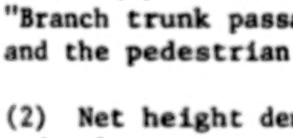


Figure 1-3 gunite support

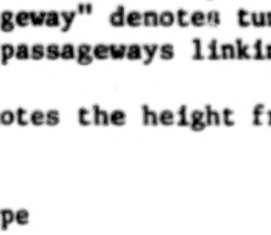


Figure 1-4 coverings

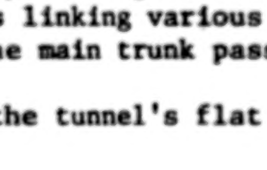


Figure 1-5. Abutting type covering

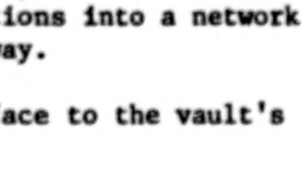


Figure 1-6. Separated wall-type covering

1-2-11. T joints may be employed in joining the tunnels. Avoid + shaped criss-crossing or intersecting.

1-2-12. The longitudinal gradient is determined by the followings:

a. The longitudinal gradient or tunnel passageway should not be less than 0.3 percent.

b. When the rooms' parallel passageways are being arranged, the longitudinal gradient of passageways should not be greater than 3 percent, generally 0.5-2.0 percent. Passageways outside the innermost airtight door should not have a gradient less than 1 percent and should slope outside the opening.

c. The ground surface gradient of a passageway or room requiring drainage of polluted water should not be less than 1 percent.

1-2-13. All pipelines not needed by the tunnel itself generally should not cut across the main body structure. Under special conditions, only water supply and heating pipelines are allowed to cross through. However, gate(s) must be installed inside the tunnel where the pipeline inlet is located. No dangerous pipelines, such as polluted water and gas pipelines, should be introduced into the tunnel.

1-2-14. Layout of pipelines must conform to the following requirements:

a. Generally building space should be utilized fully in laying air pipes. These pipes should be laid in the arched sections.

b. Electric cables, lines for illumination and communications must be laid in the open in the arched section and on the sidewalls in the ditches (trenches).

c. Water supply and heating pipelines are generally arranged on the lower side of the walls.

d. All types of pipelines must be centralized relatively on the basis of their performance requirements to prevent interference.

Section 3. Entrance and Exit Designs

1-3-1. According to the application requirements exits and entrances can be divided into main exits and entrances, general exits and entrances, and standby exits and entrances.

For peacetime needs, exits and entrances for lifting goods, machinery or equipment may be built. Exits and entrances for machinery or equipment not frequently used may be sealed tentatively.

1-3-2. Location of exits and entrances must conform to the following requirements:

a. It must be convenient to entering and leaving, and must be safe and concealed. It does not accumulate toxics easily, facilitates natural ventilation in the tunnels, and generally is not more than 200 meters away from where concealed personnel live and work.

b. The various openings must face different directions.

c. Outdoor exits and entrances should be located beyond the range where ground buildings collapse. The range of collapse is generally 0.5 times the eave height of buildings. For earthquake area with a magnitude of 8 and greater, add 0.7-1 times.

d. In areas where buildings are concentrated, when exits and entrances are unconditionally established outside the collapse range, effective measures should be taken to prevent blockage at the major or standby exits and entrances.

1-3-3. The number of exits and entrances must be determined on the basis of the use of and scale of the tunnels and natural ventilation needs. Each tunnel must have no fewer than two exits and entrances (including connected openings).

In sections where the trunk passageway goes through populated zone, two-way human traffic exit and entrance must be established every 150-300 meters.

1-3-4. Forms of exits and entrances

a. Through corridor-type or one-way ladder (or slope) exits and entrances must be used for ground passageways and dugouts (Figure 1-7, 1-8). The ladder gradient is generally around 35 degrees, not greater than 45 degrees. It is necessary to install handrails where there is two-way human traffic.

When it is necessary to use a ladder exit and entrance due to topographical limitations, a turning stairway with perpendicular exit and entrance may be employed. Perpendicular exits and entrances of turning stairways and "double-run" stairways of deeply excavated tunnels should not lead directly to the ground surface. A stairway exit and entrance should be employed near the ground surface. Short level passageways are linked in the middle (Figure 1-9).

b. The parts where the exit and entrance appear on the ground surface are generally level and have light-weight control cover plates. The outdoor exit and entrance should be properly located above the ground surface to prevent rain water from running in. When building a rain waterproof room, make sure it is in harmony with the environs; light-weight materials should be used in the construction.

c. The through-corridor- or one-way-type should be employed for tunnel personnel exits and entrances. When natural protective screens are available or incoming and outgoing motor vehicles and equipment are required, straight-through type exits and entrances may be used.

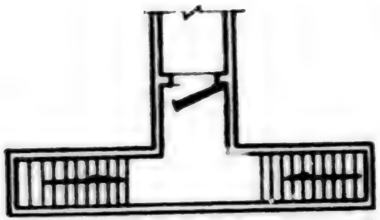


Fig. 1-7. Through corridor type exit and entrance

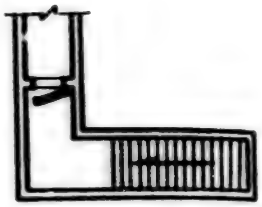
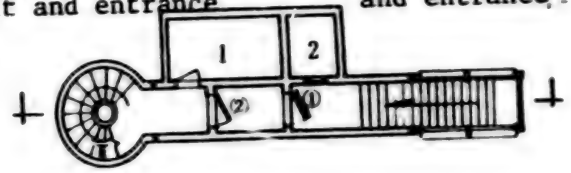
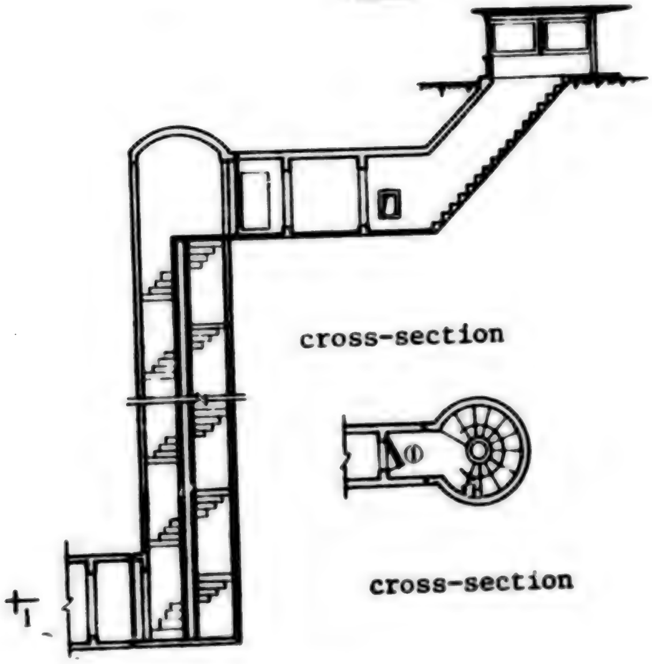


Fig. 1-8. One-way exit and entrance



Plane



cross-section

cross-section

Figure 1-9. Stairway perpendicular exit and entrance

1--blower room; 2--diffusion room; ① Airtight protective door ② Airtight door

1-3-5. The exit and entrance passageway dimensions must be adopted in accordance with the tunnel applications and Table 1-1.

Table 1-1. Exit/Entrance Passageway Dimensions Table (cm)

	Classification	Passageway			Doorway		Doorframe wall		
		Net width	net height of stairway section	net height of level section	Width	height	hinge edge width	lock edge width	door ridge height
personnel shelter tunnel	one-way human traffic	120-150	225	250	80	180	not less than 35	not less than 20 than 20	10 - 15
	two-way human traffic	150-200	225-250	275	110-130	180	not less than 40	"	"
hospital first-aid station	single track stretcher	150	225	250	80-100	180	not less than 35	"	"
	double track stretcher	200	250	275	130	180	not less than 40	"	"

Notes: (1) Net weight indicates the height from the passageway ground surface to the lower part of the arch. When a flat top structure is employed, the new height should not be less than .225 cm.

(2) When the net width of the passageway given in the table is less than the width of the doorway plus the width of the doorframe, the passageway should be partly widened in accordance with the latter.

Section 4. Openings Protection Designs

1-4-1. Airtight doors are to be installed at every exit and entrance for personnel. An airtight door may be added to the gate where a wash and decontamination room is located. An airtight door may be installed in the joint passageway of two tunnels (protection units).

1-4-2. The direction of gate openings must conform to the following requirements:

a. Airtight protection gates open outward.

b. Airtight gates generally open outward. When there are two or more airtight gates, the last airtight gate may be opened inward.

c. When the force of resistance grade of two tunnels (protection units) is different, the airtight protection gate in the joined passageway must be on the side of the tunnel with a low resistance force.

1-4-3. Anti-gas Passageways

a. An anti-gas passageway is the passageway between an airtight protection door and airtight door.

b. A tunnel gate generally has an anti-gas passageway. Two anti-gas passageways may be installed at the main door where a wash and decontamination room is located.

c. The length of an anti-gas passageway must serve to facilitate the ingress and egress of personnel [stretchers]. The anti-gas passageway with the main gate where a wash and decontamination room is located must meet the ventilation and anti-chemical requirements. Its volume must be reduced as much as possible. The ground and wall surfaces must be level and smooth and easy to wash. Floor drains must also be installed.

d. The following airtight measures for anti-gas passageways must be adopted:

1. The refilled layer outside the cover of the last anti-gas passageway of tunnels or tunnel fortifications must be airtight.

2. The slot clearance of ditch (trench) cover must be airtight, and the ditches in the last anti-gas passageway must be tightly filled.

3. Concrete should be poured onto the ground surface right on the spot. The thickness is generally 8-10 cm.

4. Concrete for the door frame wall of airtight gate and dividing wall must be poured on the spot. The thickness is generally 25-30 cm.

5. Pipelines passing through the airtight door frame wall must be airtight.

1-4-4. Wash and Decontamination Room and Simple Decontamination Room

a. When the outside of the tunnel is contaminated, the wash and decontamination room and simple decontamination room must be established at the main gate through which personnel are still coming and going.

b. Wash and decontamination room generally consists of undressing room, a shower room, and a clothing inspection room. It is located on one side of the anti-gas tunnel. An underground hospital can be established in the anti-gas passageway.

c. When there is one anti-gas passageway, the wash and decontamination room located on one side of the anti-gas passageway should be entered from the anti-gas passageway and exited from the clean zone. When there are two anti-gas passageways, patients would enter from the No 1 anti-gas passageway and exit from the No 2 anti-gas passageway (Figure 1-10). The exit and entrance of the shower room should have airtight doors. See Figure 1-11 for the plan of the exit/entrance where the wash and decontamination room is located.

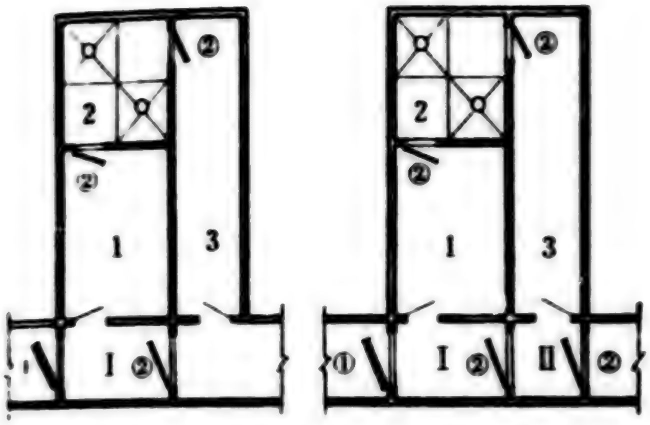


Figure 1-10. Plan for the Wash and Decontamination Room

1. Undressing room
2. Shower room
3. Clothing inspection room

I, II Anti-Gas passageways
  (1) Airtight protective door
  (2) Airtight door

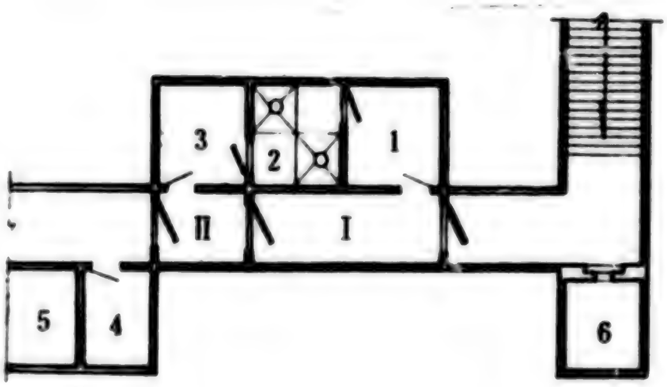


Figure 1-11. Flat surface layout of exit/entrance where a wash and decontamination room is located

1. Undressing room
2. Shower room
3. Clothing inspection room
4. Suction blower room
5. Lavatory
6. Diffusion room

d. The area of the wash and decontamination room is determined by the following requirements:

(1) The number of persons in each group entering the room is 2 times the number of shower heads.

(2) Undressing room, inspection and dressing room, 1.5 m^2 per person; shower room, 1 m^2 per person.

(3) Wash and decontamination area of hospital and first-aid station is determined by convenience of the wounded and sick in entering and leaving.

e. For the decontamination room, prepare a supply of skin disinfectants, cleansing agents, wash basins (buckets), etc. The items are generally placed on one side of the anti-gas passageway. The area measuring 6-10 cm^2 can also be located in the middle of the anti-gas passageway.

f. The ground and wall surfaces of the wash and decontamination room and simple decontamination room must be flat and smooth and easy to clean. Floor drains must also be installed.

Note: (1) "Wash and decontamination room" denotes a room where personnel are being totally decontaminated.

(2) "Simple decontamination room" denotes a room where personnel are being partially decontaminated.

1-4-5. Construction Designs of Valve, Valve Chamber, and Diffusion Chamber Must Conform to the Following Requirements:

a. Valve

(1) When the side of valve is installed in the direction of the shock waves, the depth "imbedded into" the wall must conform to the requirements (Figure 1-12) of formula (1-1).

Figure 1-12. Valve installation

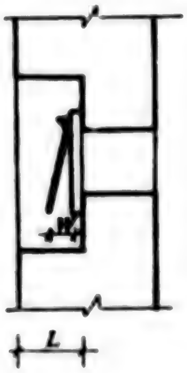
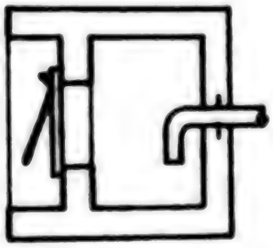


Figure 1-13

Valve room installation



$$L \geq 2W \tag{1-1}$$

Where L--depth (cm) of Valve "imbedded in"

W--width (cm) of valve's "suspended opening"

(2) When the valve is installed in the direction of the shock wave, the depth of valve imbedded into the wall should be based on the criterion that the suspended plate is not exposed on the wall surface.

b. Valve chamber

(1) The area of the valve chamber must conform to the requirements of formula (1-2):

$$V_h = (15\text{-}20)\ f_r \qquad (1\text{-}2)$$

Where V_h--valve chamber's area (m^2)

f_r--area of valve's air inlet (m^2).

(2) Length of the valve chamber (valve's rear net depth) must not be less than 1 meter. The width and height must take into consideration of the construction and repair requirements.

(3) Use of valve--when the valve eliminates the wave system, the pipe of the valve chamber's air outlet should be bent downward at 90°. (Figure 1-13)

c. Diffusion chamber

(1) The length and width of the diffusion chamber must conform to the requirements of formula 1-3.

$$L\text{--}(2\text{-}3)B \qquad (1\text{-}3)$$

Where L--length of diffusion chamber (m)

B--diffusion chamber's width (m)

(2) The width and height of the diffusion chamber should not have a difference of several times. They should be as square in shape as possible. The sectional area should conform to the requirements of formula 1-4:

$$F_k \geq 9f \qquad (1\text{-}4)$$

Where F_k--section area of diffusion chamber (m^2)

(3) The air inlet of the diffusion chamber must enter from the front, while the air outlet must be located on the sidewall 2/3 the length of the diffusion chamber from the air linlet (Figure 1-14).

1-4-6. Gate-type valves should be adopted for valves and diffusion chambers. When a suspended plate-type valve is used, manhole (50x80cm) and airtight protective covers must be installed. Floor drains should be installed in the valve and diffusion chamber, and when there is drainage, water collection wells should be sunk in a suitable location.

1-4-7. Filtration, Air Blower Rooms

a. Filtration and air inlet blower rooms must be arranged on the same side of the air inlet attenuation facilities and should be near the inlet and outlet.

b. The flat-surface layout of filtration and air inlet blower rooms must be determined by the model of the filtering equipment. It is generally arranged separately.

When the filtration and air inlet blower rooms are arranged separately, the filtration room must be located on the side of the anti-gas passageway. The gate is opened inside the anti-gas passageway, and airtight doors must be installed. The air inlet blower room must be located close to the filtration room in the clean zone (Figure 1-15). When the filtration and inlet blower rooms are combined into one room, they may be established in the clean zone and installed with airtight doors.

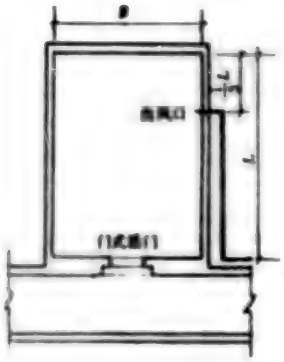


Figure 1-14. Air inlet and outlet arrangement

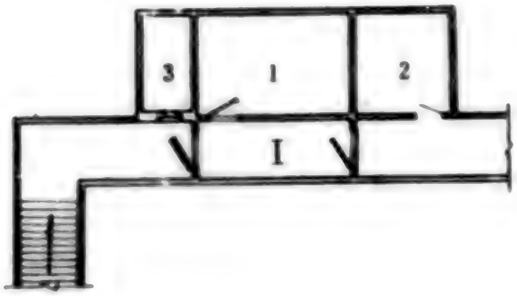


Figure 1-15. Flat-surface layout of filtration room equipped with exit and entrance

1. Filtration room 3. Diffusion room
2. Air inlet blower room

c. The ground surface and wall sides of the filtration room must be level and smooth and easy to clean and must have floor drains.

Sound-proofing measures must be taken in the air blower rooms, such as establishing soundproof rooms and doors.

1-4-8. Sealed water wells

a. A sealed water well must be sunk at the end of the drainage pipe ditch to be built. It should be located in back of the airtight protective door and in front of the first airtight door. A sealed water well must also be sunk when the airtight doors of the airtight tunnel section pass through the construction drainage pipe ditch.

b. The depth of the pipe bend submerged in the water in the sealed water well should not be less than 30 cm. A movable cover is installed above the well.

Section 5. Diesel Generator Station and Auxiliary Rooms

(I) Diesel Generator Station

1-5-1. According to its relations to the main body of the tunnel, a diesel generator station (hereafter known as power station for short) is generally divided into three types: joint passageway power station, entrance section power station, and independent power station (Figure 1-16).

The entrance section power station may be adopted when the generating sets are few in number and capacity is small.

1-5-2. The location of the power station must be consistent with the following requirements.

a. It must be as close as possible to the center of power load.

b. It must be convenient to transportation, incoming and outgoing lines and oil supply.

c. The operational zone must be at a distance and yet quiet.

d. The entrance section power station of the tunnel project must be located in the quiet, covered section.

1-5-3. The power station's engine room and control room must be located separately. The engine room is a contaminated room, while the control room is generally not permitted to be contaminated. An airtight dividing wall and an airtight observation window should be installed between the engine and control rooms. Anti-gas passageway or other airtight anti-gas facilities must be installed. The gate linking the control room and the main body of the tunnel must be located in the clean zone.

The generator control panel is fixed on the generating set at a small-capacity power station. The engine and control rooms can also be combined and located in the contamination zone.

The entrance/exit of the engine room can be located in the anti-gas passageway and airtight doors can be installed.

1-5-4. The dimensions of the engine and control rooms must be determined by the installation and inspection/repair requirements. A polluted water pool is generally established in the engine room. A lavatory may be established alone on the basis of needs. A soundproof telephone booth should be established ina power station that combines the engine and control rooms.

The power station's water storage pool and oil storage room must be arranged separately. Such water cooling equipment as vertical cooler must be near the water storage pool. A fireproof wall and fire-prevention door must be installed between the oil storage and engine rooms.

1-5-5. Vibration- and sound-proof measures, such as establishing a small soundproof room, a soundproof cover and shock absorption foundation, must be adopted. The ground and wall surfaces must be level and smooth and easy to clean. Floor drains must also be installed.

II

1-5-6. Tunnel project assured of water supply and drainage must have flush toilets.

1-5-7. Restrooms (toilets) must be installed in locations where personnel are concentrated and where they are convenient to use. They should be individually established near the air exhaust and should be protected. Each airtight section of the main passageway should have toilets.

1-5-8. Sanitation equipment is determined by the following requirements:

a. Men's toilets--one for 40-50 persons.

b. Women's toilets--one for 30-40 persons.

c. The number of urinals for men's restrooms must be the same as the number of toilets. When installing a urinal trough, every 50 cm is considered one urinal.

1-5-9. The area of flush toilet lavatory should drain toward the slope. The ground elevation should be 2 cm lower than the ground surface and the joint passageway and rooms.

III. Underground Kitchens

1-5-10. A single civil defense tunnel project generally does not have an underground kitchen. It is possible to have uniform arrangements for a network of tunnels, installing a suitable number of underground kitchens and in coordination with ground-level eateries, building underground restaurants that serve in wartime as well as peacetime. In wartime, they can be used as food processing shops.

1-5-11. When arranging an underground kitchen, the following requirements must be complied with:

a. An underground kitchen is generally established at the "mouth" of the tunnel project. It can also be established independently, linking the passageway and the main body.

b. An independent inlet an exhaust air (smoke) system must be installed.

c. All openings facing outside the tunnel must have airtight protective devices to meet the protection requirements of the tunnel's main body.

Section 6. Water Drainage, Flood Prevention, and Moisture Prevention

1-6-1. In making flood prevention and drainage designs for civil defense tunnel projects, it is necessary to proceed from the actual conditions and formulate a unified plan according to the type of tunnel, and utilize to the fullest the urban drainage system. Adopt simple, easy, and reliable methods, combining flood prevention with drainage and making use of gravitational flow to drain water.

1-6-2. Tunnel drainage designs must conform to the following requirements:

a. Utilize as much as possible the height differentials to drain the water from crevices and seepage water into the nearby river gullies and ditches or other seepage structures.

b. When the drainage outlets of ditches leading to the rivers are lower than the highest flood water level, it is necessary to adopt measures to prevent backward flows.

c. Do not cause the nearby ground buildings to sink or cave in unevenly.

d. Underground ditches (pipes) are laid every 30 to 50 meters apart and a check wall must be sunk at an intersection or turn.

e. Adopt tunnel with abutting wall cover and dig a drainage ditch outside the side wall.

f. Adopt tunnels with separated-wall covers and dig a drainage ditch outside the side wall.

g. Generally, a seepage well is not used for drainage so as to avoid polluting the underground water--i.e., the underground water resources.

h. Avoid accumulating water on the ground [above] the tunnel roof.

1-6-3. The arrangements of waterproof and moisture-proof layers must conform to the following requirements:

a. When the tunnel base plate's elevation is above the all-year-round underground water level and when there is no stagnant water, installation of a waterproof layer is not necessary. When it (the base plate's elevation--TN) is below the underground water level, a waterproof layer must be laid on the part under water.

b. When building a tunnel on a foundation that is permeably weak (clay and subclay) and there is stagnant water, take flood-prevention measures in accordance with the conditions of the tunnel underground installation and the conditions of having "forced" water.

c. Tunnel projects requiring moisture-proof measures must have moisture-proof layers.

1-6-4. Measures must be taken to keep water off the exits and entrances and air vents of tunnel projects that are near river banks and located on level and low grounds.

1-6-5. The design for flood prevention in the tunnel must meet the following requirements:

a. In accordance with the flood-prevention requirements and the situation of anti-flood materials, adopt measures to either make the structure itself flood resistant or add more flood prevention layers.

b. When the water pressure underneath the tunnel's base plate is considerable, it is necessary to use elevated arch type for the base plate.

c. When the tunnel project is being built with waterproof concrete, the structural thickness must not be less than 20 cm; the concrete's resistance to pressure must not be lower than 200 kg/cm^2. The seepage resistance grade must not be lower than 6 kilograms/cm^2.

d. The additional flood-prevention layer generally consists of ferric chloride, waterproof mortar and five coatings [of these materials]. When there is a serious underground soaking problem, it is necessary to employ flood prevention layers with externally abutted and rolled anti-flood materials.

1-6-6. When building a tunnel on rocks where underground water and crevice water develop, it is necessary to rely primarily on gravitational drainage. When restricted by topography and there is no way to have gravitational drainage, it is better to use deeply excavated tunnels.

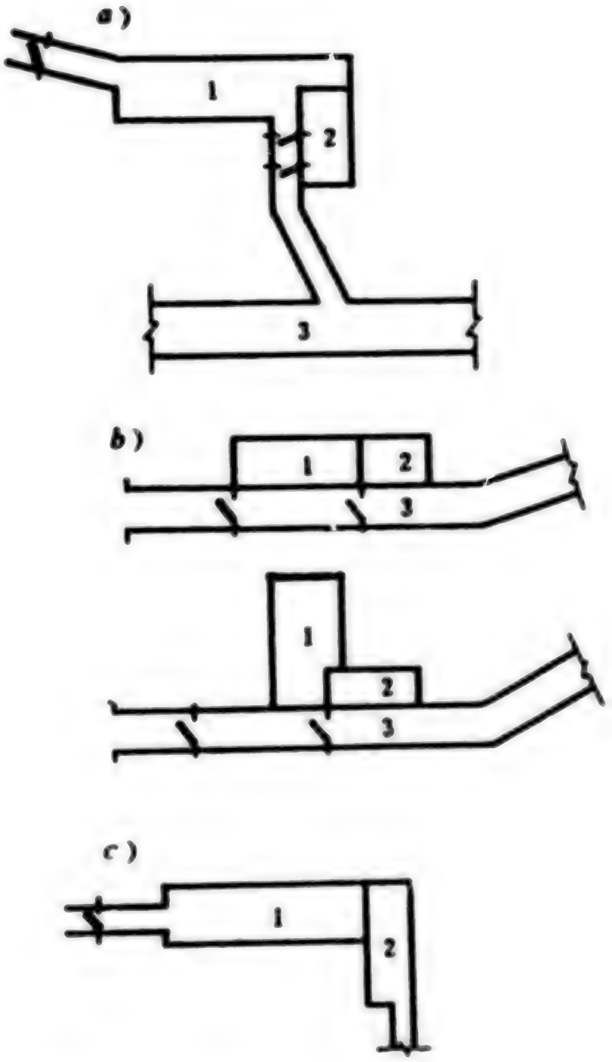


Figure 1-16. Types of power Stations

a) Continuous passageway-type power station;
b) Entrance power station; and
c) Independent power station

1. Engine room;
2. Control room; and
3. Tunnel clean zone

CHAPTER II--STRUCTURES

Section 1. General Specifications

2-1-1. The structures of civil defense projects normally bear the actions of dynamic and static loads. Dynamic load means the shock wave load from a nulcear explosion, while static load means the weights of rock, soil, and water pressure and structure.

2-1-2. In the structural design of a civil defense project, the cross-section thickness of structure, thickness of the protective layer and structural measures are generally determined by the defense of shock waves from a nuclear explosion and the initial stage of nuclear radiation.

The forces of resistance of various positions of the civil defense project and various positions of the structure must be suited to one another.

2-1-3. Measures for preventing fire and blocking (traffic jam) and making the project airtight must be taken into consideration in the structural design of the openings of a civil defense project to be constructed in areas where urban buildings are crowded and near the storage of inflammable materials. The structure's cross-section thickness must be appropriately thicker than that of explosion (blast) resistant structures.

2-1-4. Make sure that the structural design of a civil defense project is solid, suitable, and economical, and rationally select the structural form in accordance with such factors as project model, use requirements, grade of resisting forces, engineering geology, hydrological geology, building materials, and construction conditions.

2-1-5. Semi-covering, full covering, granite support or separated wall covering may be employed on tunnels and tunnel fortifications.

Whole unit-type, assembled whole unit-type, or assembled-type structures may be used on dugouts. When the assembled type is used, measures should be adopted to insure the structural whole.

Note: The rock-earth layer above the undercut tunnel project is called protective layer; the rock-earth layer above the open-cut tunnel project is known as earth-covered layer; when undercut or opencut is not yet indicated, the rock-earth layer above the tunnel project is generally known as protective layer.

Section 2. Materials

2-2-1. Structural materials of civil defense projects must meet the following requirements:

a. These materials must be obtained locally according to the prevailing local conditions. The materials obtained must conform to the specifications and use requirements.

b. Use concrete and reinforced concrete as much as possible.

c. When there are corrosive media present, anti-corrosion measures must be taken.

2-2-2. The designed strength, elastic modulus, and poission ratio of steel bars, concrete, and masonry products under the actions of static load must be selected according to the State standards.

Table 2-1. Strength-increasing coefficient of materials

Materials	Strength-increasing coefficient
I grade of steel rods	1.30
II grade of steel rods	1.15
III grade of steel rods	1.10
IV grade of steel rods	1.00
No 5 steel rods	1.20
concrete	1.40
gravels, concrete blocks, ordinary clay brick blocks	1.20

Note: (1) In the table, the strength-increasing coefficients of the same materials may be applied to the different strained conditions of drawing, pressing, bending and shearing.

(2) In the table, the strength-increasing coefficients of concrete has taken into consideration the later stage strength-increasing value of concrete with a time period of 6 months. As to parts requiring steam for curing of concrete mixed with pre-hardener, do not take into consideration the later stage increase in strength. Data given in the table must be multiplied by the reducing coefficient 0.85.

(3) Stones used as raw materials include fine gravels, coarse gravels, rubbles (lump stones).

2-2-3. During the simultaneous actions of the dynamic and static actions or the single action of dynamic load, the designed strength of the materials' dynamic force may be derived by multiplying the designed strength under the action of the static load with the increasing coefficient of the material strength as listed in Table 2-1.

2-2-4. Under the simultaneous actions of the dynamic and static loads of reinforced steel bars, concrete, and masonry products or the single action of dynamic load, the numerical value under the single action of the static load may be adopted for the elastic modulus and poisson ratio.

Section 3. Defense Against Early Stage Nuclear Radiation

2-3-1. The allowable total dose of early stage radiation entering into the the tunnel through the tunnel protective layer and exit-entrance passageway must not be greater than 50 coulombs. Tunnel designs must meet the requirements specified in 2-3-2- and 2-3-3-.

2-3-2. The minimum soil thickness required in the early stage of nuclear radiation must be determined on the basis of Table 2-2. When the tunnel protective layer is consisted of several different materials, separately multiply the thicknesses of various layers by the coefficients listed in Table 2-3 to obtain the soil thicknesses.

Table 2-2 Minimum soil thickness (cm) of protective layer for the defense of early stage nuclear radiation

Anti-shock wave ultra pressure (kg/cm^2)	1	3
Soil thickness	100	130

Table 2-3 Coefficients for converting into soil thicknesses of several kinds of materials

Names of materials	Brick-laid products dry-laid mixed rubbles	Rocks	Reinforced concrete, concrete, mixed rubble concrete, stone-laid products, concrete block-laid products
Coefficients	1.0	1.5	1.4

2-3-3. The size of doses of early stage nuclear radiation entering the tunnel from the exit/entrance is related to such factors as the total thickness of the topography near the exit/entrance, ground objects, forms and dimensions of exit/entrance, length of passageway, number of turns, protective doors (protective airtight doors). As to the civil defense tunnel projects, the resisting force of which is 1/3 kg/cm^2, the length of passageway should meet the requirements listed in Table 2-4.

Table 2-4. L_1 length (m) of passageway required for exits and entrances in defense against early stage nuclear radiation

No. of turns	Thickness of tunnel's earth roof covering (m)	Length of passageway (m)	
		resistance 1 kg/cm²	resistance 3 kg/cm²
0	1.0	4.7	
	≥2.0	3.5	
1	1.3		8.7
	≥2.0		6.5
2	1.3		4.5
	≥2.0		3.5

Note: (1) Passageway length denotes the length of the broken line inside the surface from the ground surface to the airtight door.

(2) The net cross-section volume of the passageway is 3.0 m^2. If the cross-section volume of passageway is greater than 3.0 m^2, correction should be made according to the following formula:

$$L'_t = L_t\sqrt{\frac{A_t'}{3.0}} \qquad (2\text{-}1)$$

Where L_t'--the minimum length (m) of passageway needed after correction is made.

L_t--net cross-section is the minimum length (m) of passageway computed on the basis of 3 m^2 (Table 2-4).

A_t'--Net volume (m^2) of cross-section of the passageway designed and actually adopted.

Section 4. Structural Designs

2-4-1. The designed dynamic load of civil defense structures must be determined by the attention of the rocks and earth caused by the compressed waves from the ground actions of nuclear explosion shock waves and the interactions of the waves and structures. Generally it can be transformed into an equivalent static load.

2-4-2. When making the structural design, it is necessary to superimpose the equivalent static load and static load (including rock and earth pressure; water pressure, and structural weight itself).

2-4-3. As to the structure of tunnel project open-cut in ordinary soil in natural humidity, when the refilled earth on the roof covering is less than or equivalent to one meter, the designed equivalent static load may be adopted in accordance with the following specifications:

a. When the uniformly distributed load is perpendicular to the structural roof covering, take 1.4-1.8 times the ultra pressure value of the sock waves from a nuclear explosion for reinforced concrete structures and take 1.9-2.3 times the ultra pressure value of nuclear explosion shock waves for structures of brittle materials (with masonry product-laid structure).

b. Take 0.5-0.75 times the equivalent static load value of the roof covering for the evenly distributed load perpendicular to the unit's base plate.

c. When the load of the tunnel's external wall level is evenly distributed, take 0.3-0.4 times the ultra pressure value of the shock waves from a nuclear explosion for crushed rock earth, take 0.4-0.5 times the ultra pressure value of the shock waves from a nuclear explosion for sandy soil, and take 0.3-0.9 times the ultra pressure value of shock waves from a nuclear explosion for clay soil (Take the lower limits for hard, hard plasticity and the upper limits for soft plasticity).

d. For strip footing, make the design according to the roof's action transmitted through the wall and pillars.

Note: The values given in this article are only suitable for use in structures designed according to the elastic working conditions. When the reinforced concrete structure is designed on the basis of elastic working conditions, as far as civil air defense tunnels are concerned in general, take the value specified above and multiply it by 0.75-0.85 and use the product as the designed equivalent static load.

2-4-4. As to a tunnel structure built by the open-cut method in ordinary soil in natural humidity, when the thickness of the roof's refilled earth is $H \geq 10$ (m), and the evenly distributed equivalent static load is perpendicular to the compressed wave acted on the roof, take 1.0 times the shock wave's ultra pressure value. At this time, the structure should be designed in accordance with the elastic work conditions.

Note: L is the outer "wrap" dimensions (short side, meter) of the tunnel structure.

2-4-5. The following specifications may be adopted with respects to designing the equivalent static load of tunnel projects dug out from earth below the underground water level.

a. Take 2.3-2.6 times the ultra pressure value of shock waves from a nuclear explosion for the perpendicularly and uniformly distributed load of the structural roof cover and base plate.

b. For the level and evenly distributed load of external side wall, take 1.1-1/4 times the ultra pressure value of shock waves from a nuclear explosion.

2-4-6. As to the structures of tunnels and tunnel fortifications built by the undercut method on rocks and in earth, in addition to taking into consideration the maximum pressure of compressed waves, it is necessary to consider the arch effects of natural protective layer of rock-earth on the tunnel. With respect to tunnels and tunnel fortifications capable of resisting 3 kg/cm^2 and under of ultra shock wave pressure, when the thickness of natural protective layer of rocks (types III, IV) is greater or equal to 1.0 times the "pore" span, the thickness of soil (clay and subclay of hard or hard plasticity) natural protective layer is greater or equal to 4 times the "pore" span, it is possible to make a design according to static covering.

When the above-cited conditions are not met, the design should be made according to a dynamic covering.

2-4-7. With respect to the dynamic analyses of the structures of civil defense projects, program of special design may be employed to make elastic or elastoplastic analyses. Generally it is also possible to make analyses according to the given equivalent load and by the static method.

2-4-8. When designing the structures of civil defense projects in accordance with the elastic-plastic work conditions, the allowable limiting conditions must be determined in accordance with different types of tunnels and different application requirements.

The structural operating conditions can be expressed by the allowable ductility ratio [β]:

$$[\beta] = - \frac{[y_m]}{y_r} \qquad (2-2)$$

where $[y_m]$--the allowable maximum deflection (cm) of structural parts;

y_r--deflection of plastic limit of structural parts (cm).

According to the use requirements, reinforced concrete structures are generally divided into the following three situations:

a. It is possible to design structures with fairly high use requirements and strict airtight and water-proof requirements according to the elastic operating stage.

b. It is better to design structures of ordinary civil defense tunnels having airtight and water-proof requirements in accordance with the elasto-plastic stage.

c. Design structures that do not give considerations to personnel cover during wartime and have no airtight and water-proof requirements according to the elasto-plastic operating stage.

When reinforced concrete structures and designed on the basis of the elastoplastic operating stage, the allowable ductility ratio [β] value may be adopted in accordance with the use requirements and strained condition according to Table 2-5.

Table 2-5. Allowable ductility rate [β] value

Strained condition Use Requirements	Bent	Major eccentric compression	Minor eccentric compression	Axial compression
Second situation	3.0	2.0		
Third situation	5.0	2.5	1.5	1.2

When making the design on the basis of an elasto-plastic operating condition, computation of the internal force can be made according to a specially drawn chart or program. However, it is also possible to make an analysis according to the given load (2-4-3 in the note) and the method of elastic static force.

2-4-9. When designing reinforced concrete structural parts, the following requirements should be met:

a. The distribution rate of drawn steel bars generally does not exceed 1.5 percent. When it is necessary to exceed this percentage, the [β] value of the bent structural parts must satisfy the followings:

$$[\beta] \quad \frac{0.5}{x/h_o} \qquad (2\text{-}3)$$

where x--height (cm) of concrete compressed zone

h--effective height (cm) of cross-section

b. Regarding the continuous beam support, frame, and rigid panel point, when checking the sectional shearing strength, the designed strength R_{ad} value of concrete axial compressive motive force must be multiplied by the reducing coefficient 0.8, and the distribution rate of looped steel bars μ_K should not be lower than 0.15 percent. The sum of the distribution rate μ_1 of steel bars under tension in the span of structural parts and the distribution rate μ_2 of support steel bars under tension (when the distribution rate of support steel bars on both ends are unequal, take the average value μ_2) must be satisfied.

$$\mu_1 + \mu_2 < 0.3 \frac{R_{ad}}{R_{gd}} \qquad (2\text{-}4)$$

where R_{gd}--designed strength (kg/cm^2)

c. Use sealed, fastened steel bars where the drawn steel bars are lapped and anchored. The distance between fastened steel bars should not be greater than 5 times the diameter of the main steel bars.

2-4-10. When designing the structure according to the operating stage, the following methods should be adopted in order to take the value of action force transmitted from the roof covering pillars and bar-shaped foundations.

a. When the wall and pillar are under major off-center stress, take 1.25 times the support reaction value of the roof covering under the simultaneous actions of equivalent static load and static load (rock, earth pressure, and structural weight).

b. When the wall and pillar are under minor off-center stress or axial stress, take 1.25 times the support reaction value of the roof covering under the simultaneous actions of equivalent static load and static load.

c. For the action force transmitted to the bar-shaped foundation, take the force borne by the wall and pillar and add the weight of the wall and pillar.

2-4-11. When designing the bar-shaped foundation and single pillar foundation, for the allowable soil load-bearing force, take the numerical value of static load in action and multiply the increasing coefficient listed in Table 2-6.

Table 2-6. Increasing coefficient of allowable soil load-bearing force

Soil Classification	Increasing coefficient
Pebble and dense, hard plastic subclay	5
Dense subclay	4
Fine sand of medium or greater density	3
Powdered sand of medium or greater density, Plasticable or soft subclay of medium density	2

2-4-12. When designing the structural cross-section, adopt the design method under the action of the static load. However, for the designed safety coefficient of structural parts, take the safety coefficient (Table 2-7) under the condition of static force and multiply it with 0.7 (Take 1 should the product be less than 1). For the dynamic strength of materials, take the static strength and multiply it with the coefficient listed in Table 2-1 of Chapter 11.

2-4-13. For the structural parts of brittle materials under major off-center tension and under the simultaneous actions of dynamic load or dynamic and static loads, when making the design on the basis of tensile strength control, the distance between eccentric loads may not be limited. Take 0.95y for the limited value of load eccentric distance when making the design in accordance with tensile strength control.

Note: y--the distance from the sectional center of gravity to the sectional edge where the longitudinal force is located.

Table 2-7. Designed Safety Coefficient of Structural Parts' Static Strength

Structural Classification	Tension Characteristics	Safety Coefficient
Reinforced concrete	Axial tension, bent, eccentric compression members	1.40
	Axial compression, eccentric compression, partial pressure-bearing, inclined cross-sectional shearing, torsion	1.55
Concrete	Tension members based on the calculation of pressure-resisting intensity and tension members based on the calculation of pressure-resisting intensity, partial pressure bearing	1.65
	Members under pressure and bending according to the calculation of pressure-resisting intensity	2.65
Bricks, masonry products	Under pressure	2.30
	Bending, tension, and shearing	2.50

Section 5. Structural Requirements

(I) General Specifications

2-5-1. The designations of building materials used for tunnel structures should not be lower than the specifications cited in Table 2-8.

Table 2-8. The Lowest Designations of Building Materials

建筑材料 (2) (1) 工程部位	(3) 砌体				(4) 混凝土		钢筋混凝土 (5)		喷射水
	砖 (7)	石材 (8)	混凝土砌块 (9)	水泥砂浆 (10)	现浇 (11)	喷射 (12)	现浇 (11)	预制 (13)	(6)
拱圈、顶板 (14)	100	300	150	75	150	200	150	200	100
侧(15)墙	100	300	150	50	150	200	150	200	100

Key:			
(1) Engineering location	(8) stone material	(15) side wall
(2) Building materials	(9) concrete block	
(3) masonry products	(10) cement mortar	
(4) concrete	(11) in situ	
(5) reinforced concrete	(12) sprayed	
(6) sprayed cement mortar	(13) prefab	
(7) brick	(14) arched ring roof plate	

2-5-2. Reinforced concrete structure taking dynamic load must conform to the following requirements:

a. Minimum net protective layer

(1) The inner layer of reinforced concrete structure poured on the spot is 2 cm and the outside layer (surface in contact with the enclosing rock) is 3 cm. Both the inner and outer layers of assembled parts are 1.5-2 cm.

(2) When there are actions of corrosive media, the protective layer of the outer layer should be appropriately thickened.

b. Steel bars should be distributed on both surfaces on the reinforced concrete arch or straight wall arch. The diameter of steel bars under stress should not be smaller than 8 mm and the distance (space) should not be greater than 250 mm.

c. The stress-bearing steel bars of reinforced concrete beams and plates should not be smaller than 8 mm. The reinforcing steel bars should be based on 5-10 percent of the tension-bearing arrangement with the diameter being not less than 6 mm and spacing not greater than 300 mm. No less than 0.2 percent of structural steel rods should be arranged in the pressure-bearing zone of beams and plates. The diameter of looped steel rods should not be less than 6 mm and spacing should not be greater than 200 mm.

d. The diameter of longitudinal tension-bearing steel bars for reinforcing concrete pillars should not be smaller than 12 mm. The distribution rate of all the longitudinal steel bars should not exceed 2.5 percent. The diameter of looped steel rods should not be smaller than 6 mm and the spacing should not be greater than 300 mm and, at the same time, it (spacing) should not be greater than 15d in the fastened frames. In welded frames, the diameter should not be greater than 20d (d is the smallest diameter of longitudinal reinforcing steel rod).

e. The minimum distribution rate of steel bars for reinforced concrete structural parts may be taken from Table 2-9.

Table 2-9. Minimum Steel Bar Distribution Rate (%) of Reinforced Concrete Structural Parts

Classification	Concrete Numbers		
	_ 200	250-400	500-600
All pressure-bearing steel rods of axial pressure-bearing parts	0.4	0.4	0.4
Pressure-bearing steel rods of eccentric pressure-bearing parts	0.2	0.2	0.2
Tension steel rods of bending members eccentric pressure and eccentric tension parts	0.15	0.2	0.2

f. Use welded joints for tension steel bars. When the steel rods are connected by fastering, stagger the joints and avoid placing the joints in location where there is maximum pressure. The percentage of the section occupied by the stress steel bars with joints in relation to the total area occupied by stress steel bars is as follows: in tension area, it should not exceed 25 percent and in pressure area, it should not be greater than 50 percent.

g. In the tension zone, the lengths of lap joints of steel rods and of anchorings should not be less than 30d. In the pressure area, they should not be less than 20d.

(II) Exit-Entrance Passageways

2-5-3. The following strengthening measures must be adopted in connection with exit-entrance passageways:

a. Reinforced concrete covering (linings) structures should be employed within 2-3 meters in front of the protective airtight doors and the anti-gas passageway behind the doors (See Figure 2-1) and should be built together with the door framewall. The structural section are 5-10 cm thicker than the main structure with corresponding forces of resistance. Steel rods are distributed on both surfaces of the section. Steel rod distribution in the pressure zone should not be less than 1/3 and not less than 0.2 percent of the steel rods in the tension section.

b. In-situ concrete may be employed on passageway structures 2-3 meters in front and outside the airtight doors. For tunnels with sectional thickness not less than 30 cm and with a capability of resisting an ultra pressure of 1 kg/cm^2 from the shock waves of a nuclear explosion. For tunnels capable of resisting an ultra pressure of 3 kg/cm^2 from shock waves of a nuclear explosion and the sectional thickness of which is less than 3 cm, use reinforced concrete. The sectional thickness should not be less than 40 cm.

c. The overbreaks must be completely and compactly backfilled.

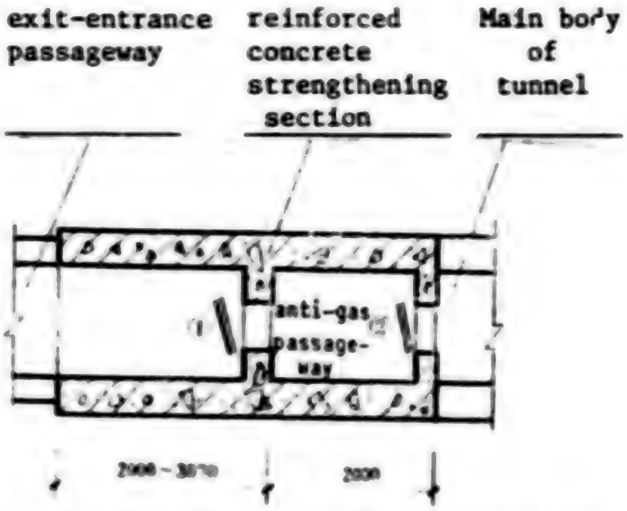


Figure 2-1. Strengthening "limits" in front and in back of the protective airtight doors

Note: (1) in the figure is the protective airtight door;
(2) airtight door

(III) Panel Point of Dynamic Structure

2-5-4. As to masonry block (or concrete) wall [and] reinforced concrete pre-fabricated arched structures, use mortar No 75 or higher for masonry work. For the wall tops, use No. 100 mortar as base mortar. Adopt the following steps for the location of the arch base.

a. Expand the arch base dimensions.

b. Install reinforced concrete cushion beams (Figure 2-2). The height should not be lower than 20 cm. The width is the same as the wall thickness. The reinforcing rods should not be fewer than 6 steel rods 12 mm in diameter.

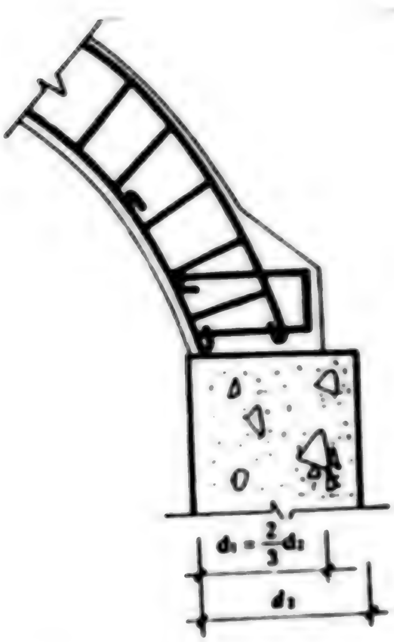


Figure 2.2. Dimensions of Expanded Arch Base

2-5-5. The requirements of nodal (panel) structure of reinforced concrete frame structure.

a. As to the terminal nodal (panel) point where the roof beam (plate) and pillar (wall) intersect (Figure 2-3), when based on rigid design, it is generally tension bearing at an outer refraction angle and pressure bearing at an inner refraction angle, and it is necessary to use welded joints. When fastened joints are used, there should be one steel rod every 10 cm among the longitudinal reinforcing steel bars in the pillar (wall), which extends to inside the roof beam (plate) and extends after being bent. The pressure reinforcing steel rods or bars on the upper layer of the roof beam (plate) should be bent and extended to inside the pillar (wall). The pressure rods are not allowed to have kinks at an inside bending angle or direct joints.

Under the effects of vibrating load, it is possible that tensile stress may appear at the inside bending angle. Therefore, extra steel bars with diameter smaller than 12 mm and spaced not more than 300 mm may be added to structures with bigger spans. A suitable number of looped bars may also be installed.

b. Regarding the intermediate panel point where the pillar (wall) and roof beam (plate) intersect, when the span of roof beam (plate) is fairly large, supports and extra reinforcing bars may be installed. (Figure 2-4)

Note: When the net span of a single span is less than 5 meters, extra bars may not be installed.

2-5-6. Outer layer steel bars of continuous arch must be bent and extended to inside the pillar (Figure 2-5).

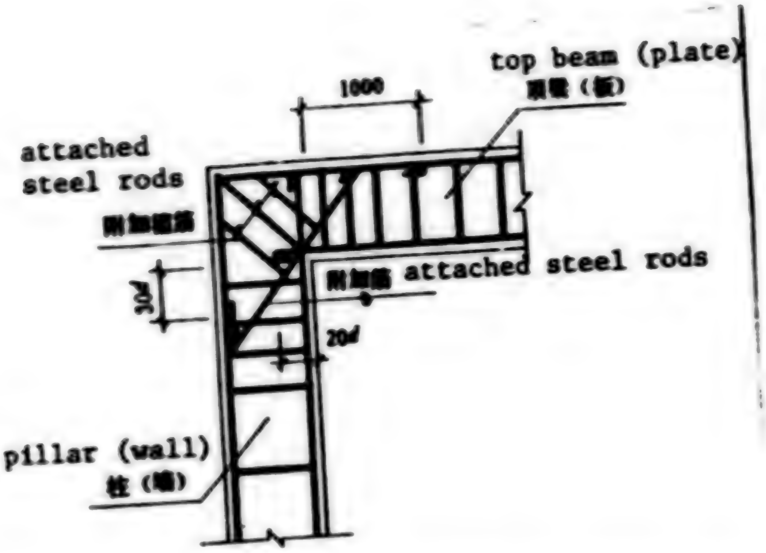


Figure 2-3. Panel point structure of framed end

2-5-7. When building a masonry (or concrete) wall reinforced concrete hyperbolic flat shall roof structure, the following requirements must be met:

a. Steel bars are distributed by zone on the shell plate. Employ orthogonal reinforced meshes on the upper and lower layers and install inclined steel bars at the corners.

b. Within the limit that the parts (members) near the edge around the shell plate are not less than 1/12-1/10 the length of the shell's short side, it is necessary to gradually increase the thickness according to the magnitude of the internal force at the location. All the steel bars of the upper and lower layers must be anchored into the edge members.

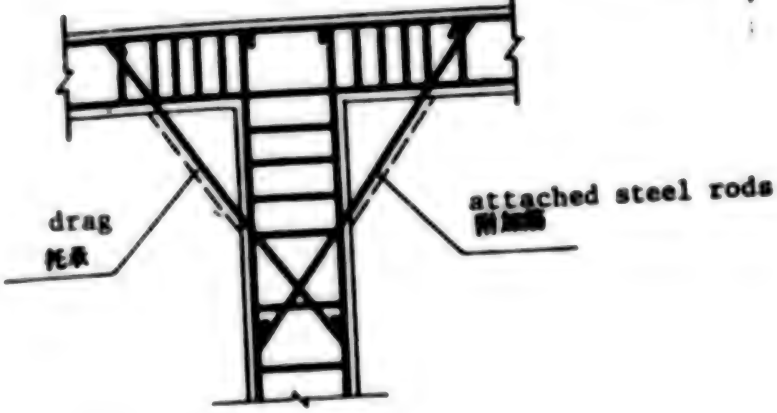


Figure 2-4. The frame's middle panel point structure when the span is fairly large

c. In addition to installing the main stress steel bars for the edge members, it is necessary to install torsional sealed looped steel bars.

d. The end panel point structure of edge member is illustrated in Figure 2-6. The stress steel bars where the ends of two edge members intersect should be lapped joint and extended beyond the edges of supports no less than 30 times the diameter of the steel bars. If required, use welded joints.

e. At the connecting point where the two edge members intersect, employ reinforced concrete pillars as supports.

f. As to tunnels capable of resisting ultra pressure of 1 kg/cm^2 from shock waves of a nuclear explosion, the thickness of masonry wall should not be less than 60 cm and the thickness of in-situ concrete wall should not be less than 40 cm.

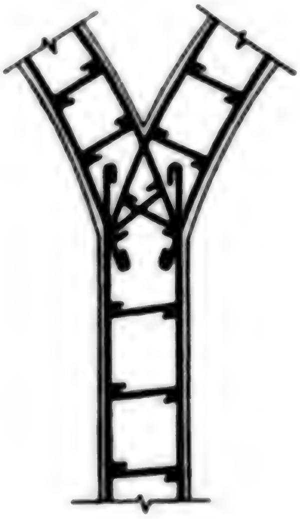


Figure 2-5. Middle panel point structure of continuous arch

g. Wall and shell top must be compactly backfilled.

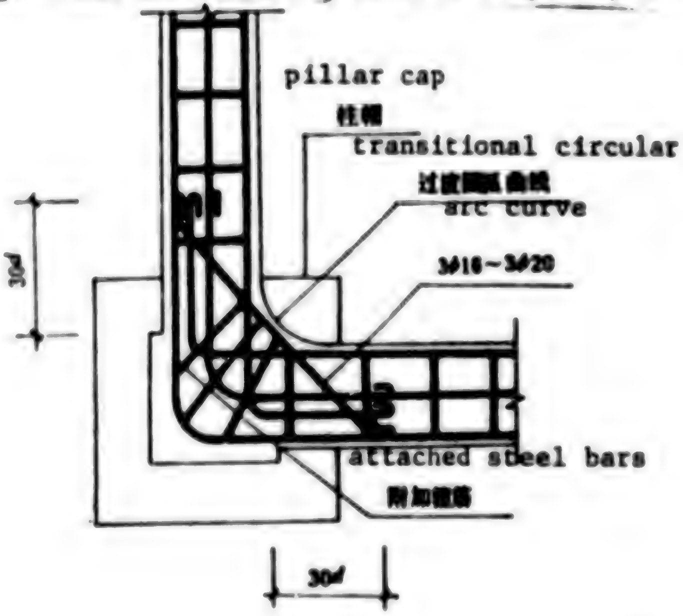


Figure 2-6. Edge beam end's panel point structure

IV. Settling and Expansion Seams

2-5-8. The installation of settling seams should be considered in the following situations, tunnels, tunnel fortifications, and dug-out structures:

a. At the intersection of in-earth solid-type head tunnel and the dynamic covering section;

b. At the intersection of soil and solid rock layer, or location where there is a big difference between hard and soft soil;

c. In location where the earthquake zone with seismic magnitude of grade 8 or greater going through the faults;

d. In river-crossing section that goes through river bed;

e. In places where there are big differences in the span, height, or tunnel load of in-earth tunnel structures;

f. In the soft and weak soft layer (such as silt earth), joint between exit-entrance passageways and the main body, and when the lateral length of tunnel is comparatively long.

2-5-9. Expansion joints should be installed on underground solid in-situ concrete or reinforced concrete structures. See Table 2-10 for spacing. However, expansion joint should not be installed if the following situations exist:

a. When dependable measures (such as arranging temperature reinforcement) have been taken during planning and construction;

b. When the internal temperature differentials of tunnel and tunnel fortifications are not great;

c. Material rocks, prefabricated concrete slabs, and assembled type reinforced concrete structures.

Table 2-10. Maximum Spacing of Expansion Joints (In Meters)

Structure Classification	Spacing
Non-reinforced concrete	20
Structural steel reinforced concrete	30
Cast-in-situ reinforced concrete	30

Note: (1) With practical experience or having taken the necessary measures, it is possible to appropriately increase the spacing.

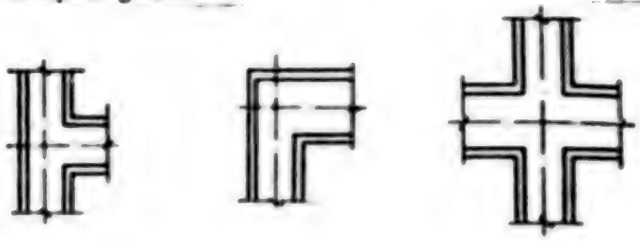
(2) The spacing of expansion seams of tunnel and tunnel fortifications structures should be reduced by 3-10 meters in accordance with the values listed in the table.

2-5-10. Considerations must be given to the coordination of the settling, expansion, and construction seams and these seams must be located in the dry sections. If they are arranged in the seepage section, water-proof treatment must be given. If they are arranged in the anti-gas airtight section, anti-gas treatment must also be given.

(V) Tunnel Joints

2-5-11. Joints of tunnels and tunnel fortifications and strengthening measures

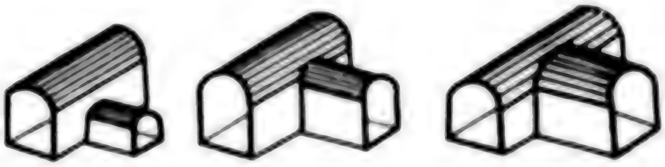
a. The plane type of joints comes in T-shape, L-shape and +-shape (Figure 2-7). Avoid adopting +-shaped joints.



丁字形 T-shape　L形 L-shape　十字形 +-shape

Figure 2-7. Plane type of joints

According to the difference in the span and height of sidewall, the joints may take the forms of sidewall intersecting, arch-semi-intersecting, and arch-plane intersecting (Figure 2-8). If the application requirements can be met, avoid arch plane intersecting and arch semi-intersecting as much as possible.



侧墙相交 Sidewall intersecting　拱部半交 Arch semi-intersecting　拱部平交 Arch plane-intersecting

Figure 2-8. Types of joint intersecting

b. Avoid plane-inclined intersecting type of joints. When this is unavoidable, the intersecting angle "a" should not be less than 60° (Figure 2-9).

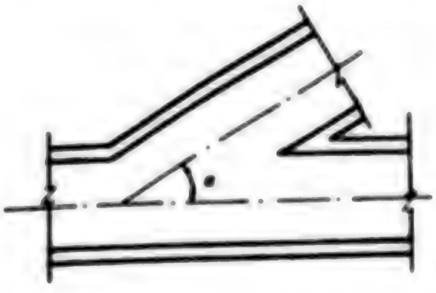


Figure 2-9. Plane-inclined intersecting joint

c. The joints should be arranged in area with good geological conditions. On the basis of the concrete conditions, separately adopt the following strengthening measures.

(1) Properly increase the material grade of the joint position.

(2) Appropriately increase the steel bar distribution rate for the joint position of reinforced concrete covering.

(3) With respect to concrete coverings, when the space is fairly large, it is possible to employ structural steel bars in accordance with 0.2-0.3 percent of steel bar distribution rate. When the span is smaller, it is possible to increase the thickness of the arch and sidewall structures having bigger spans by 5-10 cm. The concrete grade should not be lower than No. 200, and the limit of added thickness (Figure 2-10) is as follows:

When the large span of two intersecting "pores" is within 3 meters;

S = 1.0 meters

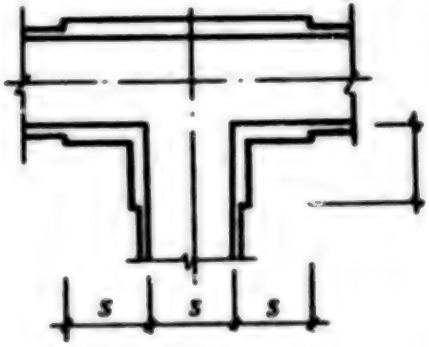


Figure 2-10. Thickening limit of tunnel joint

When the large span of two intersecting "pores" is 4 meters

S = 3.0 meters

c. The joint position of prefabricated-reinforced-concrete-member covering can be changed to in-situ pouring.

(VI) Partition Thickness and Backfill

2-5-12. The thickness of the walls of passageways (rooms) adjacent or parallel to tunnels or tunnel fortifications should be in accordance with table 2-11.

Table 2-11. Partition Thickness

Rock Classification	Partition Thickness
Class I enclosing rock	10-1.5 times larger "pore" span, but not less than 4 meters
Class (II-III$_1$) enclosing rock	1.5-2.0 times larger "pore" span, but not less than 6 meters
Class(III$_2$-III$_3$)enclosing rock, old loess or hard plastic clay	2.0-3.0 times larger "pore" span, but not less than 8 meters
Class IV enclosing rock, new loess, plasticable clay, slightly moist to moist, nonclay	3.0-5.0 times larger "pore" span
Class V enclosing rock, soft plastic-shaped clay, moist powdered sand	greater than 5 times larger "pore" span

Note: (1) I, II, III, IV, V in parentheses listed in the table denote classification of rocks. See Table 2-12.

(2) Rooms on both sides of the passageway should be staggered. The staggered distance may take 0.5-1.0 times the partition thickness.

2-5-13. Backfills outside the covering should conform to the following requirements:

a. Tunnel and tunnel fortifications in rocks

1. The same grade of concrete, rubble concrete, or snecked rubble blocks is used for the arch rings to firmly backfill the arch base position.

2. Arch rings and sidewalls should be backfilled firmly.

3. Tunnel joints and exit-entrance passageway structures must be totally and firmly backfilled.

b. Tunnels in earth, tunnel fortifications and dugouts must be firmly backfilled. For the arch base of masonry wall reinforced-concrete-prefabricated-arch or straight wall arch top structure, low grade concrete, rubble concrete, irregular rubbles or "three-seven" plaster should be used as backfill materials.

c. Tunnels build in earthquake areas to withstand the magnitude of grade 8 or greater must be completely and firmly backfilled.

Note: This specification is inapplicable to partition wall coverings.

Section 6. Gunite Supports

(I) General Specifications

2-6-1. Gunite supports are suitable for use in tunnel fortifications and civil defense tunnel projects. When facing the following geological conditions, gunite supports may be employed after testing and adopting reliable measures.

a. Rocks having strong expansion pressure from a large area of drenched water, an area partly covered with gushing water, or unexpected water

b. Clay with plentiful underground water, subclay, and loess, and all kinds of argillaceous rocks

c. Section where enclosing rocks or underground water cause serious corrosion to concrete.

2-6-2. As to tunnels and tunnel fortifications, when gunite support is used, employ explosions to "smooth the surface" and build supports in good time.

2-6-3. When using gunite support for dynamic coverings, do not use gunite support alone.

(II) Support Designs

2-6-4. The types of gunite supports and support parameters are determined by the geology, tunnel cross-section dimensions and construction techniques and other conditions where the project is located through project analogy and the necessary computations. Table 2-13 may be used for tunnels with span less than 15 meters.

2-6-5. For projects having large spans, when the stability requirements cannot be met by using ordinary gunite supports, use large pre-stressed anchor rods to strengthen the gunite supports.

2-6-6. When the span of dynamic covering is less than 6 meters, use gunite concrete support with less than 50 mm in thickness for Type II enclosing rocks. Enclosing rocks of Types III, IV and V may be used in accordance with Table 2-13. However, the thickness of gunite concrete must be increased by 20-50 mm.

Table 2-12. Classification Table of Enclosing Rocks

	Classification		Characteristics of Rock Structure	Rock saturation compression strength kg/cm^2	Underground water effects
	Type	Name			
	I	Complete hard rocks	Rocks are complete. Structural surface does not have unstable combination, shows no weathering phenomenon, and is not susceptible to weathering.	$\geq$ 800	Effects of underground water on enclosing rock stability may not be considered.
II	II_1	Complete medium hard rocks	Rocks are complete. Soft structural surface does not have unstable combination. There is virtually no weathering phenomenon and is not susceptible to weathering.	300-800	Generally effects of underground water on enclosing rock stability may not be considered
	II_2	block-shaped hard rocks	Block-shaped structure appears. Most cracks are closed and dirt not attached. Soft structural surface does not have unstable combination. Rocks may be weathered	> 600	
III	III_1	Complete, soft rocks	Rocks are complete. Rocks are not decayed or weathered or partly weathered slightly.	150-300	When underground water causes soft rocks or crack fillings to soften or when water pressure affects rock stability, it may be placed under Type IV. If the effects on rock stability are too great, it may not be necessary to lower the classification, and the enclosing rock value may be appropriately increased.
	III_2	block-shaped medium hard rocks	Block-shaped structure. Most medium hard rock cracks are closed. There are no dirt fillings. A part of hard rock cracks is open and have dirt fillings. A part of the soft structure surface has unstable combination and shows slight decay.	> 300	
	III_3	cataclastic	Cataclastic structure, but most medium hard rock cracks are closed, and have no dirt fillings. A part of the soft structure has no unstable combination. It is possible to have slight and weak decay.	> 600	
	IV_1	block-shaped	Block-shaped structure appears. Soft rock cracks do not have dirt fillings, while hard rock cracks have dirt fillings. The soft structural surface does not have unstable combination and may have slight and weak decay.	100-300	When above-cited situation in which water exists, the classification may be lowered to V.

Stable conditions of "pore" enclosing rocks	Enclosing rock pressure (ton/m^2) Perpendicular pressure	 Water level pressure	 Theory of computing rock mechanics	Representative rock samples
Span $\leq$ 15 meters unsupported "pore" enclosing rock stability	not considered	not considered	elasticity theory	granite, dioritic rocks, andesite basalt, limestone, [ferrosilicon cement, sand rock], bibbley-rock, marble, gneiss, and quartzite
Span < 10 meters unsupported "pore" is basically stable. Sidewall does not have sliding objects. In Type II$_2$, the "pore" roof or top in individual zone may have small falling rocks.	In Type II$_1$, L 10 meters may not be considered. Under other conditions, take (0.05-0.01) Ly	not considered	Theory of elasticity of theory of elasticity-plasticity	Lime cement sand rock, rubble rock, sand shale limestones, dolomite, quartz, glimmerite, and Type I rocks that are slightly weathered or poorly cemented.
				Type I rocks which are considerably cracked or slightly weathered
Span < 5 meters, unsupported "pore" enclosing rocks are basically stable. In area where the combination of individual soft structural surface is unstable, it is possible that a small number of falling rocks may appear	III$_1$ L 5m may not be considered. For other conditions, take (0.1-02) $x(L+\frac{H}{2})y$	(0-0.15)q	Use the theory of elasticity to compute the pressure of enclosing rocks; use the block form equilibrium method to determine a part of the falling rock load.	complete lime-argillaceous cement sand rocks, rubble rocks, and sandy shales
		(0.15-0.25)$_q$		Cracks (openings) are well developed. There are weak, weathered rocks under Type I or slightly weathered rocks under Type II.
			Theory of non-cohesion or theory of elasticity and plasticity	Cracks are fairly well developed. Cracks are closed and rocks with no dirt attached and weak and weathered rocks under Type I.
Span < 5 meters unsupported "rubble hole" enclosing rocks are unstable. Collapse and destruction may occur, but will not extrude, crush. Must be supported during construction period.	(0.3-0.4) x $(L+\frac{H}{2})y$	(0.25 - 0.4)$_q$		Cracks are fairly developed. Most of the sandy rocks with lime soil cement, bibbley-rock, sandy shales, and cracks are filled with dirt. Severely weathered rocks under Types I and II.

Taboe 2-12 (Continued)

VI_2 cataclastic, medium hard rocks	Cataclastic structure appears. Cracks are open, and most of them have dirt fillings. There are many soft structural surfaces and the combinations are unstable. Most of the rocks are severely decayed or weathered.	> 300	
V yolk	Non-cohesive structure appears. Hard rocks are severely weathered, dirt-imbedded. Soft rocks are slacking. Openings or cracks are completely filled with dirt.	> 100	When saturated, compute the enclosing rock pressure according to height of the water-saturated rock piller or height of the complete rock pillar.

Note: (1) in the table, L--"rubble hole" span (m),
H--"rubble hole" height (m)
y--rock/volume/weight (ton/m^2)

(2) The perpendicular pressure q and water pressure e denote the average distribution pressure of the total span and total height along the tunnel.

(3) In the pressure computation formula, the weight of backfills (from excessive excavation) is not included.

				Rocks with fairly developed cracks under Type II and all kinds of rocks with well developed cracks that are filled with dirt or severely weathered.
Span < 3 meters Supports must be close together during construction period.	$\geq 0.55 \times (L + \frac{H}{2})y$	$\geq 0.4q$		Severely weathered rocks layered with earth, fractured zone of rocks layered with dirt, unusually crushed or soft argillaceous shales and coal seams

Table 2-13. Types of Gunite Support and Support Parameters

围岩分类 (1)	坑(地)道跨度 l (2)(米)	喷锚支护 (3) 类型	(4)支护参数 (毫米)					
			混凝土厚度 (5)	锚 (6) 杆			钢筋网 (10)	
				直径 (7)	长度 (8)	间距 (9)	直径 (11)	网孔尺寸 (12)
Ⅱ	l≤8	不支护 (13)						
	8<l≤12	喷射混凝土 (14)	50					
	12<l≤15	喷、锚 (15)	不小于50 (18)	Ø18~20	2000~2500			
Ⅲ	l≤4	喷射混凝土 (14)	50					
	4<l≤6	喷、锚 (15)	50~70	Ø16~18	1000~1500	1000~1500		
	6<l≤8	喷、锚 (15)	70~100	Ø18~20	1500~2000	1000~1500		
	8<l≤12	喷、锚、网 (16)	100~150	Ø20~25	2000~2500	1000~1500	Φ6~Φ8	300×300
Ⅳ	l≤4	喷、网 (17)	50~70				Φ6~Φ8	300×300
	4<l≤6	喷、锚、网 (16)	70~100	Ø18~20	1500~2000	1000~1500	Φ6~Φ8	250×250
Ⅴ	l≤4	喷、网 (17)	100~150				Φ8~Φ8	250×250

Note:
(1) See Table 2-12 for classification of enclosing rocks
(2) No. 100 mortar is generally used for injecting into anchor bars.
(3) For ones without support, spray 20 mm cement mortar to prevent weathering.
(4) Diameter and length are listed, but spacing dimensions are not. Use anchor bars to support depending on the concrete conditions.
(5) Properly add bresssummers or steel frames to $\ell \leq 4$ meter sprayed and meshed structures and Type V enclosing rocks.

Key:

(1)	Enclosing rock classification	(10)	Reinforced mesh
(2)	Tunnel Span (m)		
(3)	Gunite Support Type	(11)	Diameter
(4)	Support Parameters (mm)	(12)	Reinforced mesh hole size
(5)	Concrete thickness	(13)	Unsupported
(6)	Anchor rod	(14)	Sprayed concrete
(7)	Diameter	(15)	Sprayed, anchored
(8)	Length	(16)	Sprayed, anchored meshed
(9)	Space	(17)	Sprayed, meshed
		(18)	not less than

CHAPTER III. PROTECTION OF OPENINGS

Section 1. General Specifications

3-1-1. According to the differences in resistance, take corresponding protective and airtight measures on openings used as exits and entrances for civil defense project personnel and equipment, air inlets and outlets, and smoke exhausts.

3-1-2. The resistance of protective and airtight equipment must be determined by such factors as tunnel's resistance, type of opening, and place where the equipment is located. The resistance of protective and airtight doors must be 1 to 2 times greater than the corresponding tunnel projects. The designed load of locks and hinges [straps] should be determined by the pressure taken by the door leaf from the shock waves.

3-1-3. The designs of protective airtight equipment must conform to such requirements as being light and flexible, safe, reliable, structurally simple, and easy to make, maintain, and repair.

3-1-4. Reinforced concrete or other lightweight and high-strength materials should be used for manufacturing protective airtight equipment and airtight doors. The structure may be arch or surface plate in shape. In-situ reinforced concrete structure should be used on door frame wall to insure that no major displacement would occur under the action of thrust. In-situ concrete structure should be used on door frame wall of airtight doors. The wall thickness is generally 25-30 cm.

Aluminum alloy materials are used for valve plates. Rolled steel may also be used. Steel structure should be used for the base.

3-1-5. The increasing coefficients of material strength under the effects of shock waves from a nuclear explosion are: reinforcing steel plate, 1.1-1.2. Aluminum alloy is not under consideration.

Strength increase is generally not considered in materials for making locks, door leaves, and airtight doors.

3-1-6. Products of finalized designs should be used for protective airtight equipment.

3-1-7. When there is a possibility that the first door of some of the main entrances may be blocked, an emergency door leaf opening mechanism must be installed.

Section 2. Protective Airtight Doors

(I) Structural Requirements of Door Leaf

3-2-1. The net spacing of tension steel bars for reinforced concrete door leaf should not be less than the diameter of the steel bar, and also must not be less than 25 mm. The net thickness of protective layer should not be less than 10 mm in relation to the reinforced concrete door leaf. For steel mesh-reinforced concrete door, it generally takes 2-4 mm.

3-2-2. The length of anchor extending into the support of the tension steel bars of reinforced concrete flat slab door leaf should be consistent with the "Regulations Governing the Designs of Reinforced Concrete Structures" currently in force. If the length of the steel bars in door leaf pressure edge is not long enough, bend the steel bar and make a hook at the end (Figure 3-1).

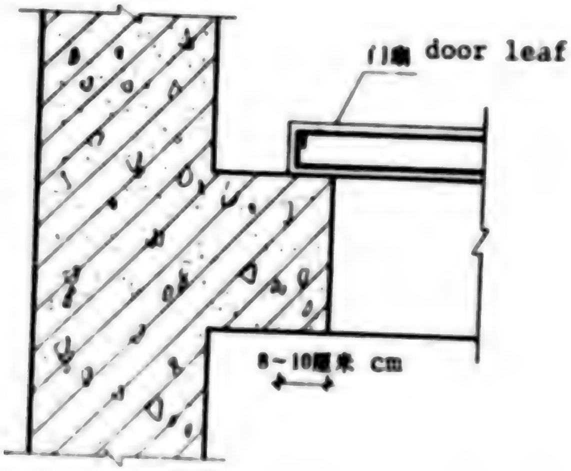


Figure 3-1. Anchor on the support of door leaf's steel bars under stress

3-2-3. For door leaf of reinforced concrete round arch door with a span not greater than 150 cm and reinforced concrete round arch door's leaf calculated on the basis of double-hinged arch, select the cross-section and symmetrical reinforcing steel bars on the basis of the maximum internal force, and use shaped steel to rim the two sides of the door leaf (Figure 3-2) or adopt other strengthening measures. Every other lateral steel bar of the inside and outside layers should be welded to the rimmed shaped steel.

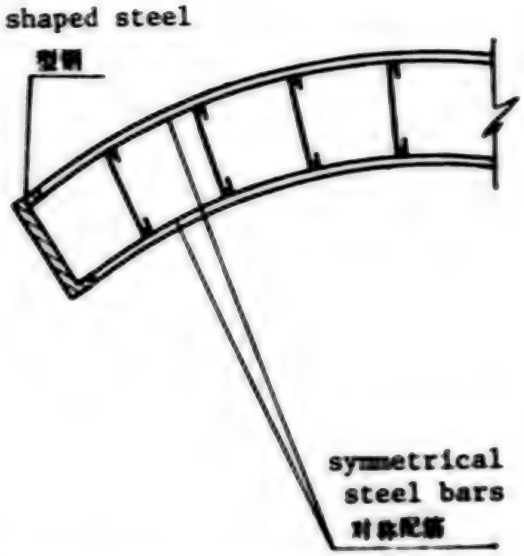


Figure 3-2. Steel bars for round arch door's leaf

3-2-4. Sealed strip fillisters must be pre-installed on protective airtight door leaf to insure that the door leaf and door frame will be kept close together when the sealing strips reach the designed compression capacity.

3-2-5. The joint of door frame and door frame wall must have sufficient anchoring steel.

3-2-6. The dimensions of protective airtight door, airtight door, and protective airtight cover are generally selected from Table 3-1 or are determined according to actual needs.

Table 3-1. Types and Dimensions of Doors

Door type	Dimensions (cm)
Protective airtight door	80 x 180
	110 x 180
	130 x 180
Airtight door	80 x 180
	110 x 180
	130 x 180
Protective airtight cover	50 x 70

Note: Door leaf pressure edge not included

(II) Locks and Hinged Leaf

3-2-7. Locks and hinged leaf are generally calculated on the basis of mechanical part designs.

3-2-8. Airtight measures must be taken in connection with the lock mechanism of airtight doors and protective airtight doors to meet the airtight requirements of door leaf.

3-2-9. Make sure that lock and hinged leaf will insure the proper opening and closing of door leaf. Lock and hinged leaf must be equipped with adjusting, tightening, and lubricating mechanisms. Make certain that effects of the positive pressure from shock waves transmitted from the door leaf will be prevented.

Internal and external control switches are generally installed in the locks. Locating devices are also installed.

(III) Door Frame Wall

3-2-10. The structure of door frame wall for protective airtight door must conform to the following requirements:

a. For the door frame wall of flat slab door, lateral tension steel bars and [erected] steel bars (Figure 3-3) should be installed on the left and right sides of the door way. The percentage of lateral tension steel bars on each surface should not be less than 0.25 percent. The diameter should be less than 10 mm and spacing not greater than 250 mm. Also, make bands (not threaded steel). The diameter of [erected] steel bar should not be smaller than 10 mm.

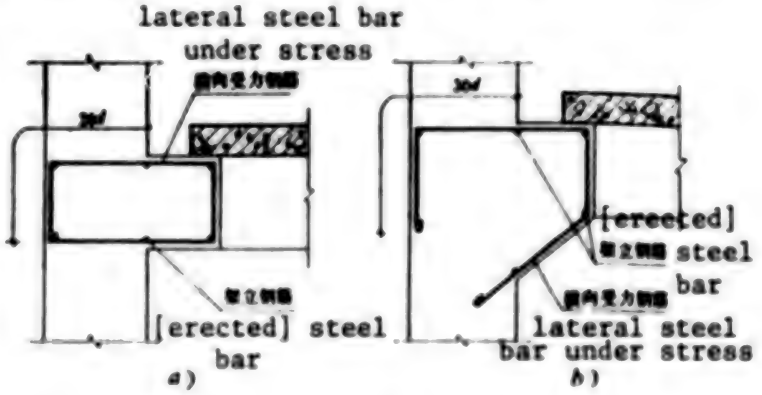

lateral steel bar under stress
[erected] steel bar
a)
[erected] steel bar
lateral steel bar under stress
b)

Figure 3-3. Flat slab door's frame wall

(a) suspended arm beam (b) bracket

b. With respect to the frame wall of round arch door, when the left and right sides of the door way conform to $\frac{N}{2C}\quad R_{ad}$ (Figure 3-4), the structure should meet the following requirements:

(1) $h_k \geq \frac{1}{3}h$, and should not be less than 200 mm;

(2) The diameter of the lateral tension steel bar should not be smaller than 12 mm and spacing not greater than 200 mm;

(3) The diameter of [erected] steel bars should not be smaller than 10 mm and spacing not greater than 250 mm;

(4) The diameter of joint steel bars should not be smaller than 6 mm and spacing not greater than 200 mm.

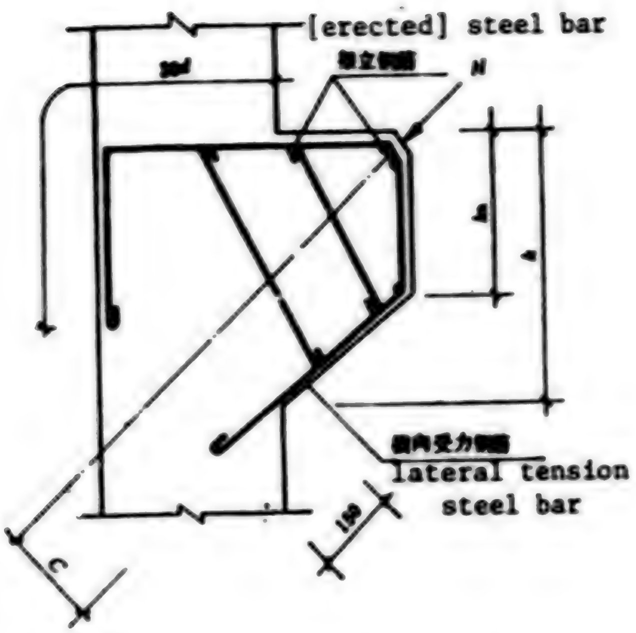


Figure 3-4. Door frame wall bracket of round arch door

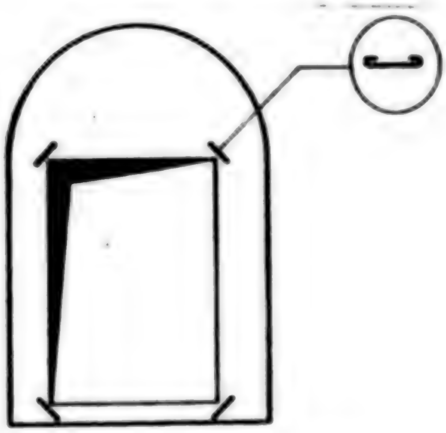


Figure 3-5. Inclined reinforcing bars at 4 corners of door way

c. Reinforcing bars for the retaining wall above the door way should be computed. However, the percentage of reinforcing bars for the outer layer should not be less than 0.25 percent; diameter of steel bar not smaller than 10 mm; and spacing not greater than 250 mm.

d. Inclined reinforcing steel bars with 16 mm-diameter should be installed at the four corners of the inside and outside layers of the door way length should not be less than 60 times the steel bar diameter (Figure 3-5)

e. The grade of concrete should not be lower than No. 250, No. 300 is generally used. The thickness is determined by computation, but for tunnel with a resistance of 1 kg/cm^2, it should not be less than 300 mm. For tunnel with a resistance of 3 kg/cm^2, the thickness should not be less than 400 mm.

Note: N--is the resultant forces (kg/cm) of the equivalent static load from the thrust along the unit length of each side of the door way.

C--is the perpendicular distance (cm) from the corner (point) under the bracket's inclined side to N extension line.

R_{ad}--concrete axial resistance of forces (kg.cm^2) under the action of dynamic load.

3-2-11. Structural joints of frame walls of the protective airtight doors and exit-entrances of the passageway must conform to the following requirements:

a. When concrete or reinforced concrete in-block coverings for the passageway are used, the door frame wall must be built together with the coverings, and the length where the tension steel bar extends into the passageway structure must not be less than 30 times the steel-bar-diameter. Should the length extending into a fairly thin structure be insufficient, it is possible to bend the steel bar 90° and make the end into a hook (Figure 3-3). The lower part of the door frame should be imbedded 300 mm below the passageway's base plate surface.

b. Use concrete, rubble concrete or rubble masonry brocks with backfills in the space between the passageway covering and "pores" of the tunnel and tunnel fortifications.

3-2-12. Joints of airtight door frame walls and the tunnel's exit-entrance structure must meet the anti-gas and airtight requirements. When concrete or reinforced concrete in-block coverings for the passageway are used for the passageway, the door frame must be built together with the [coverings].

3-2-13. Use shaped steel or reinforced concrete prefabricated door frames for airtight doors and protective airtight doors. The door leaf and frame of round arch door must be fitted together during the manufacturing process, making sure that they are level and tight. Steps should be taken to insure that they are secure and airtight.

Section 3. Suspended Plate-Type Valve

(I) Structural Design

3-3-1. The valve's designed ventilation must be determined by war time clean ventilation [volume] standards. The designed wind [air] velocity is generally at 8 m/sec.

3-3-2. Adopt the door-type structure for the valve's base seat. The air hole of the base seat (plate) should be rectangular. The side length is generally 5-15 cm. The distance between hole edges is 2-3 cm.

3-3-3. The base seat's (plate's) designed air hole area should be 5 percent greater than the needed ventilation area. The ventilation area around each suspended plate should not be greater than 0.1 m^2.

3-3-4. The width of the suspended plate is generally greater than the height and the [aperture] angle should not be greater than 15°. Generally no hole is made on the suspended plate. It is possible to take 15-20 mm on the pressure side of the suspended plate.

3-3-5. Place buffer gaskets between the suspended plate and base seat (plate) and between the base seat (plate) and valve's door frame. The gaskets are generally made of plywood. The thickness is 5-12 mm. The hardness should be 40-55 joules.

II. Wave-Dissipating System

3-3-6. The wave-dissipating system should be designed in accordance with the designed pressure of openings and the allowable residual pressure of equipment in the mechanical ventilation and power station's exhaust systems. The residual pressure following the dissipation of waves should not be greater than the residual pressure value.

3-3-7. According to the difference in resistance of forces, it is possible to select the forms of diffusion room, valve, valve-valve room, and valve-diffusion room.

CHAPTER IV. VENTILATION

Section 1. General Specifications

4-1-1. Planning of civil air defense construction ventilation should be carried out based on principles of economics, nationality, reliability, simplicity and ease of construction, depending on the required levels of protection and utilization.

4-1-2. Functions of ventilation design in civil air defense construction:

1. To insure a fresh air supply for people in the shelter for work and living.

2. To expel waste gas and to make sure that air quality meets health standards.

3. To eliminate excess heat and humidity and maintain fixed levels of temperature and humidity in the project.

4. To guarantee that the ventilation system has the required airtight protective capacity to prevent shock waves generated by a nuclear blast, chemical toxic agents, bacteria, and radioactive contaminants from entering the shelter.

4-1-3. The selection of ventilation equipment and materials should be based on reliability, durability, economy, ease of handling and ease of repair. The layout of the ventilation equipment, valves and pipes should be rational and compact, easy to operate and maintain. Length of buried pipes should be kept to a minimum.

4-1-4. Air temperature and relative humidity in the shelter should be determined generally according to the following criteria:

1. In summer, the room temperature and relative humidity in work and rest areas of command center personnel should not be higher than 30°C and 80 percent respectively; in winter, room temperature should not be lower than 10°C.

2. Indoor temperature should be between 20°C and 28°C and the relative humidity should not be higher than 75 percent during summer and winter in the surgical and emergency rooms of the hospital.

3. Naturally available heat and humidity of the shelter should be used in the personnel shelters (not work areas).

Section 2. Secure Ventilation

4-2-1. The ventilation design of civil air defense construction can be divided into three kinds according to the level of protection desired:

1. Fresh air type ventilation: the ventilation method used when the air outside the shelter has not been contaminated by radioactivity or chemical and biological agents.

2. Filter type ventilation: the ventilation method used when the air outside the project has been contaminated by radioactivity or chemical and biological warfare agents.

3. Isolation type ventilation: the ventilation method used when it is verified that contaminants have exceeded the capacity of the filtering absorbers after the air outside the shelter has been contaminated by radioactivity or chemical and biological warfare agents and the ventilation system's air intake and exhaust must be stopped. At the same time, ventilation by internal air circulation should be adopted.

4-2-2. Criteria for fresh air flow rate:

1. For personnel who keep working during hostilities, it takes 10–20 m^3/person/hour for the fresh air type of ventilation method and 2~5 m^3/person/hour for the filter type.

2. For personnel in shelters in wartime, it takes 3~7 cm^3/person/hour for the fresh air type of ventilation method and 1.5 ~ 2 m^3/person/hour for the filter type.

3. For long-term use of the shelter during peacetime, criteria similar to that for comparable structures above ground should be used according to requirements for different tasks.

4-2-3. For the isolated type ventilation, the allowed concentration (volumetric) of CO_2 inside the shelter should not be greater than 2 percent and 2.5 percent for working personnel and personnel in the shelter respectively.

4-2-4. Protective and ventilating devices like [shock] wave attenuators, dust eliminators, filter absorbers, and ventilators should be set up separately in the air intake system of the shelter according to the requirements of the different ventilation methods. Refer to Figure 4-1 for a diagram of the air intake set-up.

4-2-5. Protective and ventilating devices like shock wave attenuators, airtight valves, automatic exhaust valves, and exhaust fans should be set up separately in the shelter's ventilation system according to different situations in the shelter. Refer to Figure 4-2 for a diagram of the ventilation system.

4-2-6. If the filter type ventilation method is used, the air pressure inside the shelter should be greater than that outside by 3~5 mm of water column in order to prevent the toxic air from entering the shelter.

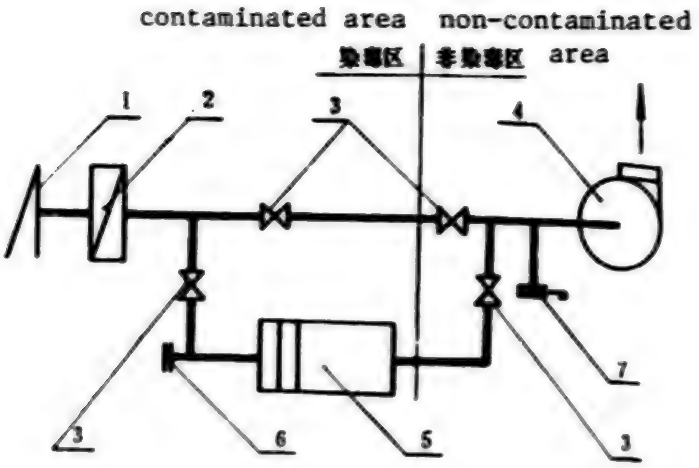


Figure 4-1. Air intake system

1--shock wave attenuator; 2--coarse filter; 3--airtight valve; 4--ventilator; 5--filter absorber; 6--air exchange stopper for the filtering absorber; 7--air intake valve for the circulating air duct.

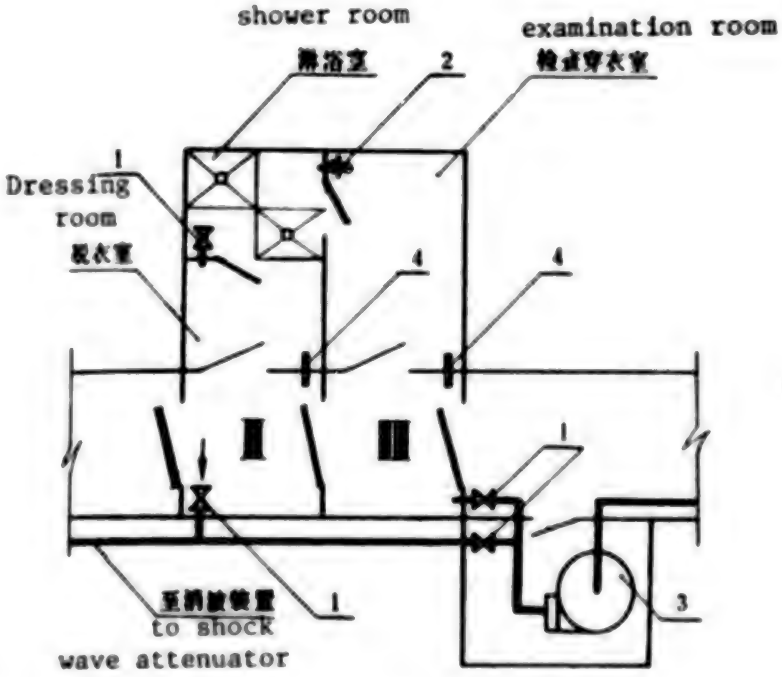


Figure 4-2. Planar arrangement of the air exhaust system

1--airtight valve; 2--automatic air exhaust valve; 3--ventilator; 4--short ventilating pipe

4-2-7. The number of automatic air exhaust valves in the exhaust system should be determined by the ventilation rate of filter type ventilation. The automatic air exhaust valves should be installed on airtight walls, but not on airtight doors.

4-2-8. Pressure gauges should be installed inside the shelter to measure the air pressure differential within and without the shelter in the filter type ventilation and should be conveniently located in the air exhaust machinery room.

Section 3. Natural Ventilation

4-3-1. In peacetime, natural ventilation should be used for civil air defense construction, whenever feasible.

4-3-2. Depending on the project utilization requirements, maximum use of favorable terrain, surface conditions and weather conditions should be made and the adopting of the necessary supplementary measures--thermal and wind potential--should be done to provide the motive power in the shelter for natural ventilation.

4-3-3. If natural ventilation is used in the shelter, a simple planar arrangement should be used to reduce resistance, to avoid blind angles, and to induce air circulation. Rooms that open onto other rooms and terminal rooms that extend too deep should be avoided. Ventilation louvres should be set up in walls and over doors in order to facilitate air convection.

4-3-4. The installation of natural air ventilation ports should be based on the planar arrangement of the shelter, area of the structure, and flow system of the air current. Each shelter (defense unit) should have at least one air inlet and one exhaust outlet. The exhaust outlet must be higher than the air inlet. To insure that the direction of air current inside the shelter does not change seasonally, the placement of the air inlet should always be at the point of positive potential with respect to the dominant air current, and the placement of the air exhaust outlet should be situated at the point of negative potential relative to the dominant air current.

4-3-5. The natural air ventilation ports should be compatible with the airtight protective requirements of the shelter.

Section 4. Mechanical Ventilation

4-4-1. Mechanical ventilation should be used in shelters that use the filter type of ventilation. If natural ventilation alone cannot meet the ventilation requirements of the shelter, the shelter should be supplemented by mechanical ventilation.

4-4-2. Computations of ventilation flow rates in the shelter should be made separately according to whether the ventilation flow rate is of the wartime fresh air type or filter type, or long-term peacetime ventilation.

4-4-3. The larger value of the following two air flow values should be used as the flow rate of wartime fresh air type ventilation.

1. The ventilation rate is computed in accordance with 4-2-2.

2. The ventilation rate is computed by taking into consideration that ventilation is needed to expel excess heat, humidity and toxic substances.

4-4-4. The larger value of the following two air flow values should be used as the flow rate of filter type ventilation.

1. The ventilation rate is computed in accordance with 4-2-2.

2. The ventilation rate is computed on the basis of the air leak rate calculated from the air replenishment rate as stipulated for anti-gas passageways and the air leak rate when the shelter is operating with excess.

4-4-5. The hourly air leak rate of a shelter made of poured concrete can be computed as 4 percent of the total volume of the shelter's sealed area when the excess pressure is 5 mm of water column; for a shelter covered by other materials, it is determined by experimental measured data in similar shelters.

4-4-6. In order to maintain a fixed level of normal pressure, the total exhaust rate of the exhaust system of the shelter should be less than the total air intake rate of the intake system.

4-4-7. The ventilation frequency for different kinds of exhaust chambers for fresh air or peacetime ventilation can be computed as in Table 4-1.

Table 4-1. Frequency of air exchange in different kinds of air exhaust rooms

Kind of room	Frequency of air exchange (times/hr)
Toilet	10 ~ 15
Reservoir area between water pumps, cesspool area between waste water pumps	1 ~ 2
Washing area, bath	3 ~ 5
Oil storage room of diesel power generating station	5 ~ 6

4-4-8. The quantity of air intake and air exhaust should be determined according to the scale and usage of the shelter. For back-up inlets and outlets, measures should be taken to prevent blockages.

4-4-9. Air (smoke) intake and exhaust outlet equipment should meet the following requirements:

1. Air intake outlets should be located in an unblocked, clean area. The lower edge of the port should be 0.5 higher than ground level in order to prevent dust being sucked into the shelter. If the outlets of the air ducts and vertical ventilation shafts are exposed aboveground, measures should be taken to avoid outlets from being filled with water.

2. The ports for air intake and air (smoke) exhaust should not be located together. Air intake ports should be located on the windward side of the annual prevalent wind direction and should be lower than the air (smoke) exhaust ports.

3. To insure that the ventilation requirements for the cleaning area and anti-gas passageways is met, an air exhaust port should be located at the entrance/exit of the cleaning area for those shelters equipped with cleaning facilities.

4-4-10. The air circulation system of one chamber should meet the ventilation requirements of all the chambers. Forced draft blower from the upper part and exhaust from the lower part are generally adopted for the chambers. For machine equipment rooms where large amounts of residual heat must be expelled, forced draft blowing in the lower part and exhaust in the upper part should be used.

4-4-11. Rooms that produce large amounts of toxic substances (such as toilets, battery storage rooms) should be relatively close together and situated close to the intake section of the exhaust duct. Negative pressure should be maintained inside these rooms.

4-4-12. The choice of ventilators should meet the following requirements:

1. Manual ventilators may be selected if there is no internal power source in the shelter. Manual and electrical dual-purpose ventilators may be selected where there is an internal power source that cannot guarantee a continuous power supply. Electric ventilators may be selected if a continuous power supply can be guaranteed by the internal power source.

2. To compute pressure loss in the ventilator, a factor of 10~15 percent should be added; to compute the air flow rate in the ventilator, a factor based on the air leak rate of the ventilator should be added. For air ducts made of brick or concrete, a factor of 10 ~ 15 percent should be added. For metal air ducts, a factor of 0 ~ 10 percent should be added.

3. When the air flow rates in the ventilation systems of the fresh air type, filter type, and long-term peacetime type differ greatly and their difference exceeds the characteristic curve for a ventilator (or performance chart), ventilators should be selected case by case. [Note: The air leak rate of the air ventilation duct may be omitted from the computations for air ventilation ducts]

4-4-13. The materials used in the air ventilation duct should meet the requirements of being moisture-proof, corrosion-proof, and economical. Brick air ducts, concrete air ducts, and sheet metal and plastic air ducts should be set up according to local conditions and availability of materials. When plastic air ducts are used, applicable fire-prevention regulations should be followed.

4-4-14. Fullest use should be made of the shelter's structural spaces when arranging ventilation ducts. Suspended and partitioned air ducts can be used. Overhead construction is recommended when sheet metal air ducts or plastic air ducts are used. When a floor air dict is used, the elevation of the bottom of the air duct cannot be lower than that of nearby water drainage ditches and measures to prevent water drainage should be used.

4-4-15. Pipeless forced draft blowing should be used if the heat and humidity requirements of the shelter are not high where the architectural planar arrangement is relatively simple.

Section 5. Air Treatment

(I) Computational Parameters for Air Outside of the Shelter

4-5-1. For summer ventilation, the average value of the medium monthly temperature of the hottest month over the years should be taken in computing the dry bulb temperature of the air outside of the shelter. An annual average not assuring 400 hours moisture content value for the average year should be taken in computing the moisture content of air outside the shelter. [Note: 'Over the years' here means over the most recent 10 years recorded by local meteorological stations. If the station has records of less than ten years duration, statistical results should be determined after data has been analysed and compared with nearby stations]

4-5-2. For winter ventilation the average values of the medium monthly temperature and relative humidity of the coldest month over the years should be taken respectively in computing the dry bulb temperature and relative humidity of air outside the shelter.

4-5-3. The average value of the coldest three months of winter over the years should be taken to compute the atmospheric pressure, average wind velocity, prevailing winds and their frequency outside the shelter; in winter (summer), the average value of the coldest (hottest) three months over the years should be used in the above computations.

(II) Computation of Heat and Humidity Loads

4-5-4. The heat and humidity loads inside the shelter include:

1. The rate of heat and moisture dissipation from human sources.

2. The rate of heat and moisture dissipation from machine installations and pipes.

3. The rate of heat dissipation from lighting.

4. The rate of heat conduction and moisture dissipation in the surface of the surrounding protective structures.

5. The rate of moisture dissipation brought about through food and drink and washing.

4-5-5. The rate of heat and moisture dissipation of human bodies, equipment and ducts and heat dissipation due to illumination can be determined by ventilation designs used in industrial and civil engineering.

4-5-6. When the depth [of the structure] is greater than 10 m, the heat of the conducting of the surrounding protective structure Q can be calculated according to (5-1).

$$Q = KF\,(t_n - t_o) \qquad \text{(Kcal/hr)} \qquad (5\text{-}1)$$

in which

t_n-----air temperature (°C) inside the shelter (or Chamber)

t_o-----internal temperature °C) of the ground

F------inner surface area (m^2) of the shelter (or chamber)

K------coefficient of heat conduction

$$K=\frac{1}{\frac{1}{\alpha_n}+\frac{1\cdot 13\sqrt{aZ}}{\beta\lambda}} \qquad (\mathrm{Kcal/m^2/hr/°c})$$

α_n-----the heat exchange coefficient of the surface of the surrounding protective structure, is usually taken as 4~5 (Kcal/m^2/hr/°C)

a------thermal conductivity coefficient of the ground (m^2/hr)

λ------thermal conductivity coefficient of the ground (Kcal/m/hr/°C)

Z------heating time during the pre-heating period (hr)

β------correction coefficient of the shape of the shelter (or chamber)

for a square shelter or chamber (spherical equivalent)

$$\beta=1+\sqrt{F_0}$$

for a rectangular shelter or chamber (cylindrical equivalent)

$$\beta=1+0.38\sqrt{F_0}$$

F_o-----Fourier coefficient

$$F_0=\frac{aZ}{R_0^2}$$

R_o-----equivalent radius of the chamber's cross section when the ratio of length over width is larger than 2:

$$R_0=\sqrt{\frac{S}{\pi}} \qquad \text{(cylindrical equivalent)}$$

when the ratio of length over width is less than 2:

$$R_0=0.62\sqrt[3]{V} \qquad \text{(cylindrical equivalent)}$$

S------the area cross section of the shelter or chamber (m^2)

V------the volume of the shelter or chamber (m^3)

4-5-7. The heat of conduction of the surrounding protective structure can be calculated from the relevant sources if the shelter is buried in a depth less than 10 m.

4-5-8. The ground initial temperature t_o ought to be computed by using experimental data from the same type of shelter or from similar shelter. When no experimental data is available, the following method can be used to calculate t_o:

1. t_o can be calculated according to equation (5-2) for a shelter buried at a depth of less than 10 m.

$$t_o = t_{dp} \pm A_o e^{-\sqrt{\frac{\omega}{2a}}\cdot x} (℃) \qquad (5\text{-}2)$$

in which

t_{dp}----the annual average temperature (°C) of the local ground surface over the years.

A_o-----the annual wave amplitude of the local ground surface temperature over the years.

In summer $A_o = t_{dr} - t_{dp}$

In winter $A_o = t_{dp} - t_{de}$;

t_{dr}----monthly average temperature (°C) of the hottest month of the local ground surface over the years.

t_{de}----monthly average temperature (°C) of the coldest month of the local ground surface over the years.

e------base of natural logarithm, $e = 2.72$.

ω------frequency of the annual temperature fluctuation (radian/hr)

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{8760} = 0.000717;$$

a------thermal conductivity coefficient of the ground (m/hr);

x------the calculated depth (m) from the ground level to the desired underground level which is at the initial temperature.

$\pm$------'+' is for summer calculation
'$-$' is for winter calculation

2. The annual average local ground surface temperature over the years can be used for shelters buried at a depth greater than or equal to 10 m. i.e.,

$$t_o = t_{dp} (°C)$$

3. Equation (5-3) can be used as a correction factor if there is a big difference between the sea level elevations of the shelter site and the meteorological station.

$$t_o' = t_o - \frac{H_s - H_q}{M} (℃) \qquad (5\text{-}3)$$

in which

t_o'-----the initial temperature (°C) of the ground after correction from the sea level altitude.

H_h-----Sea level elevation (m) of the shelter's entrance/exit

H_g-----Sea level elevation (m) of the neighboring meteorological station

M------the air temperature drop coefficient due to difference in altitude, usually $M = 200$ m/°C

4-5-9. Empirically measured data should be used to calculate the moisture dissipation rate of the covering surface of the shelter. If no empirical data is available, $1 \sim 2$ gm/m^2/hr can be taken for concrete wall-adhering covering, 0.5 gm/m^2/hr can be taken for linings and coverings detached from the wall.

4-5-10. The moisture dissipation rate generated by personnel working and living in the shelter (such as food and washing) can be calculated on the basis of 30 40 gm/person/hr.

(III) Heating and Moisture Reduction

4-5-11. For shelters requiring heat, industrial waste heat, city heating networks, or ground level boiler rooms near the shelter should be fully exploited as heat sources. For heat ducts leading into the project, protective airtight devices such as valves should be installed on the lead-in ducts inside the shelter.

4-5-12. Combined measures in the moisture reduction design of the shelter from the standpoints of designs in the architectural structure, flood control, and waste water disposal should be aimed at strictly controlling the moisture sources in order to reduce the moisture dissipation rate in the shelter.

4-5-13. Air ventilation moisture reduction measures should be used when the moisture content of the air is low. Air ventilation moisture reduction by temperature elevation should be used when there are regions of available heat sources near the shelter.

4-5-14. Solid hygroscopic agents or localized moisture reduction by dehumidifier should be used in rooms where there is a high priority for moisture removal.

Section 6. Ventilation of Diesel Power Generating Stations

4-6-1. The design of ventilation in diesel power generating stations should not only expel the residual heat and fumes in the engine rooms, but also satisfy the requirement for providing sufficient air for combustion needed in the diesel engine.

4-6-2. Independent air intake and exhaust systems should be installed in the engine room of the power station. If air from the main part of the shelter is used to ventilate the engine room, toxic substances from places such as the battery storage room and toilets should not be discharged into the engine room.

4-6-3. When fresh air type ventilation is used, the air intake and air exhaust rate should fulfill the following requirements:

1. If air cooling is adopted in the engine room (air outside of the shelter is used for ventilation and temperature lowering), computations should be based on the ventilation rate required to eliminate the residual heat.

2. If water cooling is used in the engine room (water is used as a cooling agent to cool the air inside the engine room), computation should be based on the ventilation rate required to expel the toxic substance.

3. The air exhaust rate in the engine room should be equal to the air intake rate minus the air consumption rate of diesel combustion.

4-6-4. The air consumption rate of diesel combustion can be calculated on the basis of 5 m^3/horse-power/hr. In the fresh air type ventilation the air inside the engine room should be used for combustion. In the isolated type of ventilation, air outside of the shelter should be used directly for diesel combustion, and the resistance for the automatic tapping system should not be more than 100 mm in water column in order to reduce the level of fumes in the engine room.

4-6-5. Open-type circulation should be used in the water cooling system of the diesel cylinder. The heat dissipation rate of the diesel engine, generator, and smoke exhaust pipes should be computed to arrive at the residual heat of the engine room. If closed type of circulation is used, the heat generated by the cooling water from the diesel engine cylinder into the engine room should also be computed.

[Note (1) open-type circulation is a system in which the cooling water, directly expelled after cooling the cylinder, may be partially drained into a mixed water reservoir.

Note 2 closed-type circulation is a system in which the cooling water, after passing through the heat dissipator, flows back to the cylinder in repeated cooling circulation]

4-6-6. Shower facilities, surface type cooler, or heat dissipation water tank that comes with the diesel engine can be used to lower engine room temperature if the shelter's water flow rate and temperature can meet engine room temperature drop requirements. If the heat dissipation water tank that comes with the diesel engine is used to lower the temperature of the engine, the cooling system of the diesel engine cylinder should be changed from a closed-type to an open-type circulation in order to channel the cooling water into the heat dissipation water tank for cooling of air circulation in the engine room.

4-6-7. A combination of air cooling and water cooling should be used in engine rooms if there is insufficient water in the shelter or the water temperature is too high. If the air outside of the engine room is contaminated, measures to lower the temperature by water cooling should be fully exploited.

4-6-8. The amount of fresh air in the control room of the diesel power generating station connected to the shelter should be supplied by the shelter's ventilation system. If supply must come from the engine room of the power station, airtight valves and noise attenuators should be installed on air ducts leading into the control room.

4-6-9. Ventilation and air exchange facilities should be set up in auxiliary rooms located between oil storage areas, water reservoirs and water pumps of the power stations. For frequency of air exhaust and air exchange rate, see Table 4-1. Air exhaust pipes ought to lead into the air exhaust system of the power station. But fireproof valves should be installed on air exhaust pipes that lead into oil storage areas.

Section 7. Ventilation for Other Types of Shelters

(I) Air Ventilation in Transformer Rooms

4-7-1. The ventilation in the transformer room should be designed to expel the residual heat inside the room. Room temperature should not be higher than 35°C.

4-7-2. The residual heat of the transformer room should be equal to the sum of heat dissipation in the empty load loss and short circuit loss.

4-7-3. Ventilation and adjustable valves should not be installed in the transformer room. The distance between the air duct inside the room and high voltage bus bars should not be less than 0.5m. Fireproof valves should be installed on the intake and exhaust ducts of the transformer room.

(II) Ventilation for Small Storage Facilities

4-7-4. The temperature and relative humidity of the air inside storage facilities requiring temperature and humidity regulation should be calculated according to Table 4-2.

Table 4-2. Air temperature and relative humidity inside the warehouse

Kind of warehouse	Temperature (°C)	Relative Humidity (%)
Food	less than 25	less than 75
Ammunition and medicine	lower than 30	less than 70
Others	lower than 30	less than 75

4-7-5. Storage facility ventilation is generally a combination of closed-type and natural type. Mechanical ventilation may also be used as needed.

4-7-6. Designs for reducing moisture inside the storage facility can be based on 4-5-12 to 4-5-14.

(III) Ventilation for Passageways

4-7-7. Generally, ventilation is used for personnel evacuation passageways. Air intake and air exhaust ports for natural ventilation should be installed depending on the actual situation.

4-7-8. Ventilation for passageways used by motor vehicles should be designed with the purpose of expelling toxic gases. At wartime the allowable level [volumetric] of carbon monoxide should not be higher than 0.2 percent.

4-7-9. Natural ventilation should be used for these passageways. When that cannot fulfill requirements, mechanical ventilation may be used. The magnitude of the ventilation rate should be determined by factors such as the number of vehicles, their speed, loads, and the kind of fuel used.

CHAPTER V. WATER SUPPLY AND DRAINAGE

Section 1. Water Supply

5-1-1. Depending on factors such as particular usages in the shelter, the degree of desired hygiene and local weather conditions, the daily water consumption rate standard should be based on Table 5-1.

Table 5-1. Standards for Daily Water Consumption Rate

Items of Water Consumption	Unit	Water Consumption Rate
Drinking water	liter/person/day	3-5
Rinsing and washing water	liter/person/day	5-10
Flush toilet water	liter/person/day	24
Water consumption for patients		
In-patient	liter/bed/day	60-80
Out-patient	liter/person/day	6-8
Cooking water	liter/person/day	4-6

Note: The water consumption rate for drinking, washing, and flushing toilet is included in the water consumption rate for the in-patients. The water consumption rate for working personnel in the hospital and first-air stations should be computed as that of the shelter personnel.

5-1-2. The quality of daily drinking water should meet national requirements in "Hygiene Standards for Daily Drinking Water."

5-1-3. Water quality, temperature and pressure and the rate of water consumption in the facilities should be determined by the shelter's requirements.

5-1-4. There are four kinds of water sources in the shelter:

1. Independent internal water source. This is the water source inside the shelter intended for an independent shelter or a protective unit of a joint shelter.

2. Regional internal water source. This is the water source inside the project intended for the shelters within the scope of the project.

3. External underground water source. This is the underground water source set up adjacent to the shelter, generally intended as a reserve water source and is well-protected.

4. Lead-in water source. This is the city tap water drawn into the project and is mainly intended as a reserve for the shelter's daily supply.

5-1-5. The following requirements should be met for water source facilities of the project.

1. A technique vs. cost comparison should be employed according to the water sources situation and utilization requirements.

2. For the same shelter, more than one water source should be available to insure a sufficient water supply.

3. Internal water sources, especially independent ones, should be fully exploited.

4. Reservoirs or water tanks should be used in shelters where internal water sources cannot be provided or are inadequate for a supply of water. The water storage rate should be determined by the number of personnel during wartime and the duration of their stay.

5. The internal water sources and water storage facilities should be located in a clean area within the shelter.

6. Joints in pipelines between an independent water source and other water sources should be protected from contamination.

5-1-6. Potable water reserve cisterns or tanks should be set up separately. If they are set up together with non-drinking facilities, measures should be taken to ensure that the drinking water is not used for other purposes.

5-1-7. The selection of a water supply system should meet the requirements of water quality, temperature, pressure, and flow rate in the various water supply functions of the shelter in accordance with the overall water supply situation. With a rational technology-to-cost ratio, a circulating water supply system should be set up, and excess water pressure should be exploited as much as possible.

5-1-8. Gravity flow from reservoirs or tanks placed at a higher level should be used wherever possible to supply water for daily needs inside the shelter.

5-1-9. Water supply pipes inside the shelter should be exposed.

5-1-10. Anti-earthquake and flooding measures must be taken at those points where the pipes pass through the outer walls of the shelter; they must be made airtight at the point where they pass through the wall.

5-1-11. Lead-in water supply pipes should be made of steel. Corresponding durable control valves should be placed inside the lead-in ports of the shelter.

Section 2. Water Drainage

5-2-1. Generally, waste water is drained by gravity or by waste water pumps.

5-2-2. In order to prevent a build-up of negative pressure, generally water will not be drained out during the period the shelter is sealed off. But water may be drained out if the drainage rate is smaller than the water supply rate and also a continuous water supply is maintained.

5-2-3. When the shelter is sealed off, all items of water consumption must be controlled and water drainage rates reduced. Waste water collected from the cooling of internal facilities should be directed to flow back to the original reservoir. If heat generated from the facilities is substantial and calculations show that a single level reservoir cannot meet the water consumption requirements, double or multi-level reservoirs can be adopted. The lowest tier of a multi-level reservoir should not be filled with water and its volume should not be included as part of the effective [total] volume of the reservoirs.

5-2-4. The volume of the cesspool should meet the following requirements:

1. The volume of the cesspool drained by the waste water pumps should include the readjusted and reserve volumes. The readjusted volume should be determined by the in-flow waste water rate and the operation of the water pumps; the reserve volume should be calculated on the basis of the total waste water in-flow rate during the period of shelter isolation.

2. The reserve volume of a cesspool with induced drainage cannot be less than the overall volume of waste water inflow during the period the shelter is sealed off and served by filter type airconditioning multiplied by a safety coefficient of 1.25.

3. The reserve volume of a cesspool with a gravity drainage system should be computed on the basis of the in-flowing total volume of waste water for the period during which the shelter is sealed off.

4. Generally, the reserve volume of the cesspool should not be utilized for other purposes.

Note: If drainage conditions stipulated in 5-2-2- are met, the reserve volume of the cesspool does not include the volume occupied by the out-flow during the period of isolation.

5-2-5. Cesspools should be located in a clean area of the shelter, generally at the lower reaches of tne drainage pipe near the entrance of the shelter. If toilets and washrooms are set up together, they can be installed under these areas.

5-2-6. Floor drains should be installed in the toilets, washrooms and other water consumption areas with a slope of not less than 1 percent toward the floor drain and with tneir upper comb-like surfaces 5 ~ 10 mm lower than the surrounding ground level.

5-2-7. If there is a possibility of back-up, flow-control valves and gates should be installed in the drainage outlets.

5-2-8. Measures to counter poison gas and blast should be provided in the drainage pipes of the shelter in order to prevent poison gas and atmospheric shock waves from entering the shelter through the drainage pipes.

Section 3. Cleaning and Disinfection

5-3-1. Water consumption rate should be followed as in Table 5-2.

Table 5-2. Water Consumption Rate for Cleaning and Disinfection

Items of cleaning and disinfection	Unit (each time)	Water consumption rate in cleaning and disinfection
cleaning and disinfection of personnel		
shower	liter/person	30-40
washing	liter/person	5-10
Floor cleaning and disinfection	liter/m^2	5-10

Note: Higher values should be used for shower water consumption rate in washing and disinfection for personnel of hospitals and first-air stations.

5-3-2. Generally, the temperature for personnel hot water shows is around 37-40°C. Heating facilities should guarantee that all showers be ready for use within 30 minutes after heating.

5-3-3. Cooling water for diesel engines or other facilities is used as a source of hot water for cleaning and disinfection. Measures should be taken to prevent the cooling water from becoming contaminated.

5-3-4. A water supply system consisting of single pipes should be used in the shower set-up. A combined water tank or a cold and hot water mixer should be set up in the screening room.

5-3-5. Water sprinklers or fire hydrants equipped with rubber hoses for disinfection should be installed in chambers and passages of the shelter's main entry and exit parts which may suffer contamination from waste water. The service radius of the sprinkler or fire hydrant generally should not exceed 25 m and the outlet water water pressure should not be less than 10 m of water column.

5-3-6. Floor drains or drainage outlets with a diameter of not less than 75 mm should be installed in chambers and passageways that require disinfection. Generally, protective measures should be taken at drainage outlets.

5-3-7. Waste water from cleaning and disinfection should be drained separately.

Section 4. Firefighting

5-4-1. Those shelters in which there is a danger of conflagration should be provided with a supply of water for firefighting or light firefighting gear, fire alarm systems and emergency telephones based on the probability of fire breaking out and the extent of the danger.

5-4-2. Shelters provided with a water supply for firefighting should [also be] equipped with facilities to drain off the excess firefighting waste water.

Section 5. Cooling Water and Oil Supply for Diesel Generating Stations

5-5-1. Cooling methods such as water cooling (direct flow method), air cooling (circulating method) or air water cooling (direct flow and circulating method) should be used in the water-cooling system of diesel generators according to the types of water sources, meteorological and air-conditioning conditions.

If the water cooling system is adopted, a repeated utilization method should be employed for the water consumption for air-conditioning in the generator room and the water consumption for cooling the diesel engine. Self-circulated utilization should be considered in the water consumption for air-conditioning.

If the air cooling system is adopted, the water refilling rate for a standing type of air-cooler generally should be computed on a rate of 2 liter/horsepower/hour.

5-5-2. The water supply for diesel generators can originate from inside the project, from external water source and reservoir of the power station. Generally, the water supply comes from the reserve reservoir of the power station during the period the shelter is sealed off. The volume of the reservoir is computed according to Table 5-3.

Table 5-3. Water Storage Time

Conditions of water sources	unit	water storage time
without self-provided internal water source	hour	2-4
without self-provided external water source	hour	8-10
using urban tap-water source	day	3-5

5-5-3. The temperature regulation of cooling water in diesel engines can be either a combined pipeline or a combined water reservoir regulation. If combined pipeline regulation is adopted, maximum utilization should be made of the thermostat on the diesel engine. If combined water pool regulation is adopted, the volume of the combined water reservoir should be computed according to the cooling water rate of the operating diesel engine within 5 ~ 15 minutes at a set operating power.

5-5-4. Measures to assure an ample supply of water in the cooling system before starting up the diesel engine.

5-5-5. Water-temperature thermo-meters should be installed on the lead-in and lead-out pipes of the diesel engines. Water level gauges and pressure meters should be installed on drainage pipes. Bleeder valves should be installed on pipes at local high points.

5-5-6. Diesel generators should have at least a 7 to 15-day fuel oil supply for operation.

5-5-7. Fuel oil should be stored in two or more oil tanks, oil drums or oil reservoirs.

Oil lead-in, oil lead-out, oil drainage pipes, air ventilation pipes and an oil level meter should be provided for oil tanks, drums and reservoirs. Oil tanks should be fitted with cover plates, which are in turn fitted with maintenance hatches. Hatches should be provided for oil tanks and reservoirs.

Oil lead-out pipes should be placed 0.15~0.20 m above the bottom level of the oil tanks, drums and reservoirs.

5-5-8. Depending on the actual situation, the oil delivery connection well can be located below the upper part of the oil storage space or outside the protective airtight door. A gate with the proper strength should be installed near the oil-delivery lead-in pipe inside the shelter.

5-5-9. Measures to prevent seepage and leakage should be adopted for the oil tanks, drums and reservoirs.

CHAPTER VI. ELECTRIC POWER AND LIGHTING

Section 1. General Specifications

6-1-1. This chapter is applicable to designs of a power supply of less than 10 KV for lighting in tunnels and excavated shelters.

6-1-2. The design of electric power supply for lighting of the shelter has to be safe, reliable, economical, and convenient to install and maintain.

6-1-3. In the electric equipment of the project, moisture- and mildewproof products should be used and efficient procedures should be devised to guard against dampness and rotting. Routine maintenance schedules should be emphasized.

Section 2. Power Supply

6-2-1. The power sources of the projects include:

1. External power sources

2. Independent internal power sources

3. Regional internal power sources

6-2-2. An overall integrated installation plan is needed for the power sources in the shelter.

1. All sites should be properly connected to external electric power sources.

2. Internal independent power sources should be installed in major shelters.

3. For other shelters, maximum use should be made of regional internal power sources or a switch made to these units' underground power supply facilities during hostilities.

6-2-3. The total transformer capacity of the external power sources should be determined by the total calculated loads for all the power-consuming equipment in the projects.

6-2-4. The number and the output capacity of the diesel generating units in the internal power supply should be determined by the following requirements:

1. The total capacity of the units in operation should be determined by the total calculated loads of all the power-consuming equipment in the projects together with the continuous power rating for each generating unit after allowed corrections are made in an actual operation condition.

2. In determining the capacity of a generating unit, the capacity of the squirrel-cage starter motor should be taken into consideration. Table 6-2 should be used in determining the percentage value of the full-voltage starter cage motor capacity of the generating unit.

3. In designing an independent internal power source for the project, at least two generating units should be used in the power station. Thus when one unit encounters problems, the other set can supply power for all the important loads.

A single generating unit may be installed in the power station, when a neighboring internal power source is connected and used as an auxiliary power source for the important loads.

6-2-5. Operation modes for the power source

1. Internal and external power sources should be operated in different series. Usually the external power source is the main power supply source.

2. Operation in parallel is preferred if two units or more of the diesel generators of the same capacities and the same model are operated at the same time. When the load distribution is even, operation in different series can be adopted.

3. Reliable measures should be adopted to prevent the error of operation in parallel among the different power sources intended for operation in different series.

6-2-6. The generally used wiring mode for low-voltage bus-bars is a single bus-bar or sectional single bus-bar. If a sectional bus-bar is used, sectional bus-bar switches should be installed.

6-2-7. Means of guaranteeing the cut-off and switching of the important power supply loads and cutting down the secondary loads should be provided.

6-2-8. It is inadvisable to use the same return circuit for both the communication load and the operation load.

6-2-9. Single-phase power-using equipment should be distributed as evenly as possible over a three-phase circuit.

Section 3. Electrical Circuits

6-3-1. The following requirements should be met in choosing the cross-sections for the insulated electric wires and cables:

1. The allowed current-carrying capacity should not be less than the calculated power load of the circuit.

2. The requirement for mechanical strength should be met in the smallest cross section of the wire. Aluminum wire should not be less than 2.5 mm^2; copper wire, except for the head lamp wire which is not less than 0.5 mm^2, should not be less than 1.0 mm^2.

3. The allowable values for circuit voltage loss from the low voltage side output from the transformer or the low voltage bus-bar from the generator to the terminals of the power-using equipment should not be greater than those specified in Table 6-1.

Table 6-1. Values of allowed circuit voltage loss

Kinds of power-consuming equipment	Allowable loss in voltage (%) Normal circumstances	Special circumstances
Electric motor	5	10
Lighting	5	10
Thermoelectricity (illumination below 36 V)	10	
Ordinary communication facilities	5	

4. The choise of cross-section for the insulated wires and cables should be compatible with the protective devices.

6-3-2. Aluminum conductors can generally be used in the electrical circuits but under the following conditions, copper conductors should be used:

1. Secondary connection wires and control cables in the control panel.

2. Wires and cables in mobile equipment.

3. Rooms in a flammable, explosion-prone and corrosive environment.

6-3-3. For power cables and lead wires, all-plastic cables, plastic insulated wires should be used, as far as possible.

6-3-4. The external power supply for the project should employ buried, lead-in cables, as far as possible.

6-3-5. In the installation of power cables and lead wires, the following requirements should be met:

1. Cables are usually laid in the open along the roof of the project, side walls or supporting frames of the air-ducts.

2. Insulated wires are usually laid in the open by using Plastic cleats, procelain cleats, or procelain knobs. But raceway wiring (or plastic-sheathed wires) should be used in rooms with a flammable, explosion-prone or corrosive environment or in situation when the operating voltage of the wires is above 220V, and also when laying wire horizontally or vertically along side walls, at a height of less than 1.8 meter, and when laying wire horizontally along the ceiling at height lower than 2.0 meters.

6-3-6. The connections to insulated lead wires usually are pressure joints or soldered joints. At the joints anti-corrosion and tight sealing measures should be used.

6-3-7. Proper sealing procedures should be used when electric raceways and wiring must pass through a protective door, a hermetically-sealed protective door, a hermetically-sealed door's partition wall or door frame. Additional raceway outlets should also be provided with hermetic seals. Zinc-plated steel tubing should be used.

Section 4. Electric Power and Illumination

6-4-1. Usually a magnetic starter is selected as the starting control device for the cage-type motor. An iron-clad switch can also be chosen when the motor capacitance is less than 4.5 KW and it has enough power to be controlled by starter.

6-4-2. When the cage-type motor is started at full voltage, its terminal voltage has to fulfill the following requirements:

1. A reserve motor usually cannot have a voltage lower than 85 percent of the specified value; a frequently operated motor cannot have a voltage lower than 90 percent of the specified value.

2. The allowable value of the motors can be less than 85 percent if the motors can be guaranteed to sustain the starting torque exerted by the mechanical equipment and also if the waves induced in the system are not powerful enough to damage the other electrical parts under normal working conditions.

The capacitance of the full voltage starter cage motor as a percentage of that of the generator and transformer can be determined by Table 6-2.

Table 6-2. The capacitance of the full-voltage cage-type starter motor as a percentage of that of the generator and transformer

Kind of power source	Excitation voltage control method	Capacity of the full-voltage cage-type starter motor (%)
Diesel generating unit	normal voltage control	10
	carbon resistor type automatic voltage regular	12 ~ 15
	Silicon controlled rectifier voltage regulator with exciter [auxiliary generator]	15 ~ 25
	Silicon controlled mutually and self-excited constant voltage installation	15 ~ 30
	Tertiary harmonic wave excitation	50
Transformer		Reserve starter 30
		Regular starter 20

6-4-3. Motors should be equipped with the following protective set-up:

1. Depending on specific circumstances, overload protection is used. Short circuit protection must be used.

2. Two-phase operation protection should be used to protect the continuously operated three-phase AC motors. But it may be skipped if the following conditions exist.

a) The stator is one with star-shaped wiring which is also equipped with an overload protection.

b) There is always a guard on duty, and the facility is equipped with two-phase operation instructions.

The two-phase operation protection set-up should be equipped with a three-phase thermo-electric relay with a differential conducting panel. When limited by conditions, other special protective devices can be substituted.

3. Voltage loss protection should be employed when the operating machinery does not allow for self-starting or the capacitance of the power sources cannot satisfy the requirements for self-starting.

6-4-4. It is recommended that an automatic water level control be installed in the motor of the sewage pump and the water drainage pump. Readily accessible push-button on/off switches should be installed in all remote-controlled and automatic motors.

6-4-5. The switch-box for illumination and power should be installed inside the hermetically-sealed door (except for the generator rooms of power stations), near the center of the electricity load, where it is easy to maintain, and placed in a relatively dry place.

6-4-6. Incandescent and flourescent lamps are the usual sources of illumiation. In situations where brighter lighting is needed, other kinds of light sources can be used.

6-4-7. 220 V AC is adopted as the voltage of electric sources for illumination. The voltage should not be higher than 36V if the lowest point of the lamp's position is 2.0 meter below ground level and no other safety measures are available.

6-4-8. Fuse protection of 15A or smaller is usually used for each single phase return circuit in the illumination loads of the projects. Independent fuse protection should be used inside the hermetically-sealed door for the illumination return circuit from inside the project to outside the hermetically-sealed door.

6-4-9. A criss-cross power supply with two-phase or three-phase return circuits is generally used for the lighting in the main passages designed for emergency evacuation. Separate power supplies should be used for passage illumination and room illumination.

The illumination loads of the projects should be controlled region by region and section by section.

6-4-10. Except for the surgery room in a hospital, a special emergency-use illumination power supply is not generally installed.

6-4-11. The minimum illumination standards for important offices and passages in the project should meet the specifications of Table 6-3.

Table 6-3. Illumination Standards

Name	Lowest illumination (lux)	Name	Lowest illumination (lux)
Command office	100	control room	75
chief's office	75	diesel engine room	50
staff's office	50	shelter room	10
surgery room	75	disinfection room	10
medical clinic	50	exit	50
communications office	50	passageway	5

Note: The above figures do not include localized illumination.

Section 5. Electric Power Stations

6-5-1. Diesel generator units with automatic voltage regulation and electric or air starters are generally chosen for electric power stations. Air-compressors should be installed in a power station using air-started units, with a compressed air cylinder for each unit. Pipelines for the starter and for adding air should be interchangeable; seamless steel tubes should be used; and air releasing valves should be placed at the terminals of the pipelines.

6-5-2. The arrangement of the generator room should fulfill the following requirements:

1. The arrangement of the generator room should satisfy the requirements for safety of operation and maintenance of the equipment and convenience of moving. Compactness and neatness should be emphasized. Criss-cross pipelines should be avoided and cables should be kept dry.

2. The two configurations in general use for generator rooms are with the axis of the generator units parallel to the axis of the room (Figure 6-1) and with the axes perpendicular (Figure 6-2). The dimensions of the generator room should be less than the values stipulated in Table 6.4.

3. In addition to placing the generator units according to the dimensions in Table 6-4, the placement of auxiliary equipment, equipment for simple repairs of machines, tool boxes, spare parts, storage cabinets, duty desks and slop sinks should also be worked out.

4. Air ducts and other equipment unrelated to maintenance and repair should not be installed in the space above the generator units or within 2.2 m of the maintenance passageways on both sides of the generator units.

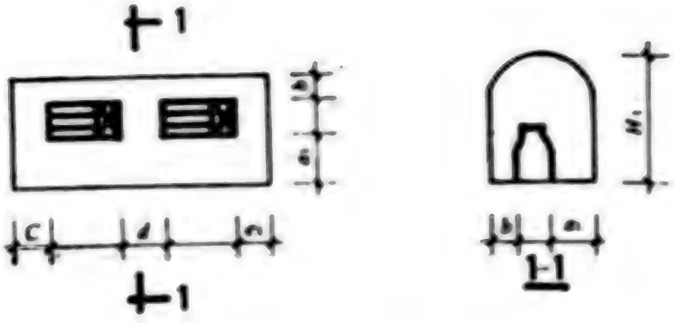


Figure 6-1. Parallel set-up

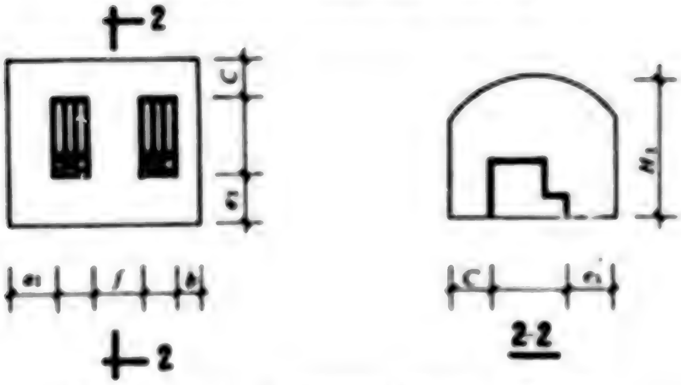


Figure 6-2. Perpendicular set-up

Table 6-4. Dimensions of Generator Rooms for Generator Units in Common Use (Meters)

Types of diesel engines			4125-C	4135D 6135D	4160 6160A	12V 135D
Rated capacity of Generator (KV)		below 40	50	40,50 64,75	60,84 120	120
Working area (with transportation passages)	a_1	1.2	1.8	1.5	1.8	1.8
working area	a_2	1.2	1.8	1.5	—	1.2
lateral area	b	0.8	0.8	0.8	1.0	0.8
diesel engine end	c	1.0	1.2	1.2	2.0	1.2
interval between diesel engine and generator	d	1.2	1.5	1.5	2.0	1.8
generator end	e_1	1.0	1.2	1.2	1.5	1.8
generator end (with transportation passages)	e_2	1.5	1.5	1.5	—	1.8
interval between generator units	f	1.5	1.8	1.8	—	1.8
clear height of generator room	H_1		4.0	3.5	4.0	4.0
	H_2		4.3	4.0	—	4.3

Note 1: Values for c and d include dimensions of engine oil cooler

2: Dimensions of the generator room do not include the area occupied by ancillary equipment

6-5-3. The system for removing the fumes of the diesel engine should fulfill the following requirements:

1. The diameter, thickness and construction materials of the discharge flue should be determined by such factors as the type and model of the diesel engine, resistance to the allowed values for excess pressure from the shock waves, and heat resistance and corrosion resistance.

2. The discharge flue of the generator room should have a clearly designed overhead structure and effective heat-insulating materials, such that its surface temperature does not exceed 60°C.

3. When there are two or more generator units, the exhaust flues of all the diesel engines should merge into a single main flue. Each branch flue should be equipped with an exhaust valve. Flexible joints should be used to connect the exhaust ports of the diesel engines with the branch exhaust flues.

4. The slope of the discharge flue should not be less than 0.5 percent, and water drainage valuves should be installed at the lowest point of each section.

5. Procedures to prevent obstruction, or damage from rainwater or shock waves should be employed on those fume discharge flues that lead out of the tunnel area.

6. The shock wave-attentuation system for the fume exhaust of the power station should be determined by the allowable excess pressure for the generator unit in question.

6-5-4. Insofar as possible water cooling should be used for the lubricant cooling system of the diesel engine. Space should be allocated for storage of lubricants in the electric power station.

6-5-5. First aid and fire-fighting facilities should be maintained in the approximate rooms of the power station.

6-5-6. An intercom system is needed if the generator room is separate from the control room. If the generator room and control room are combined, a telephone and signal system is needed for communication with the main office.

6-5-7. The configuration of the control room should satisfy the following requirements:

1. The switchbox in the control room usually employs a single column arrangement. The width of the passageway in front of the switchbox should not be less than 1.5 m. For a switchbox installed away from the wall, the width for the passageway behind the switchbox should not be less than 0.8 m.

The height of the control room should be determined by the requirement that the safe distance from the highest point of the switchbox's upper exposed conductor to the ceiling of the tunnel cannot be less than 0.5 m. The clear height of a flat ceilinged chamber is generally not less than 2.5 m, and the height of a room with an arched ceiling is generally not less than 2.2 m.

2. Ventilation ducts and other equipment should not be installed above the switchbox. If other equipment or ducts have to be installed in the passageways in front

of or behind the control [room] switchbox, they must conform to the electric safety distances and not obstruct the maintenance crew.

3. Besides arranging for a switchbox and other power distribution equipment in the control room, space should be allocated for duty desks and electrician's supply cabinets. There should also be space reserved for a rest area for duty personnel in a suite or room adjoining the control room.

4. Installation of storage batteries inside the control room is strictly forbidden. The doors of the control room should open outward.

Section 6. Zero Grounding and [Direct] Grounding

6-6-1. A neutral point direct grounding system should be used for the generator and the transformer. Zero grounding protections should be adopted for the metal casings of electrical equipment, for metal structures, ductwork, shelters, and doors that are close to the charged circuits, and for the low-voltage output wire terminals of safety transformers.

6-6-2. Low voltage wires leading in from the external power sources should be grounded at the iron-footings of the insulator for the overhead line at its entrance to the tunnel. The zero [neutral] wire should be repeatedly grounded at the tunnel entrance. As for valve-type lighting arrestors, the iron footings of their insulators should be equipped with special nearby grounding device in addition to being connected to the main grounding device of the tunnel through the metal skins on power cables and grounding wires.

6-6-3. The following requirements for grounding to guard against static electricity should be followed in the case of fuel tanks and fuel pipelines:

1. Very good anti-static grounding should be used with metal fuel tanks and pipelines.

2. Reliable anti-static grounding procedures should be used for nonmetal fuel tanks, such as laying anti-static grounding conductors along the inner walls, and leading the conductors to a reliable ground outside of the tanks.

3. When there is a common ground for the anti-static grounding device and other grounding devices, its ground resistance must equate to the smallest value for resistance among the parts.

6-6-4. Grounding devices should meet the following requirements:

1. The structural steel reinforcing rod network of the tunnel should be fully exploited as a natural ground. When the actually measured grounding resistance value proves to be inadequate and when there is no structural steel reinforcing rod network available within the tunnel for grounding purposes, grounding poles can be driven into soil of low resistivity inside the tunnel, or artificial grounding bodies can be installed in the reservoirs, filter wells, or cesspools.

Grounding wires leading out from two different entrances should be used whenever it is difficult to install a ground inside the tunnel, or whenever an external ground has to be used because the ground resistance of a grounding device inside the project is inadequate.

2. If the structural steel reinforcing rod network is used as a ground, soldered joints should be used at the intersections of stress-bearing rods and the distributing rods. All joints in the grounding device should be firm and reliable.

3. Flat steel bars of 25 mm x 4 mm and round steel rods 12 mm in diameter are commonly used as grounding lines. The grounding lines should be regularly protected from rusting and sprayed with anti-corrosion paint.

6-6-5. The values for grounding resistance should not exceed those specified in Table 6-5.

Table 6-5. Grounding Resistance Values

Grounding Device		Ground Resistance (ohms)
Generators or transformers	total capacity 100 KVa	4
in parallel	total capacity 100 KVa	10
Grounding for high voltage equipment		10
Repeated ground and ground for anti-lightning equipment		10
Equipment grounding for static electricity		30

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